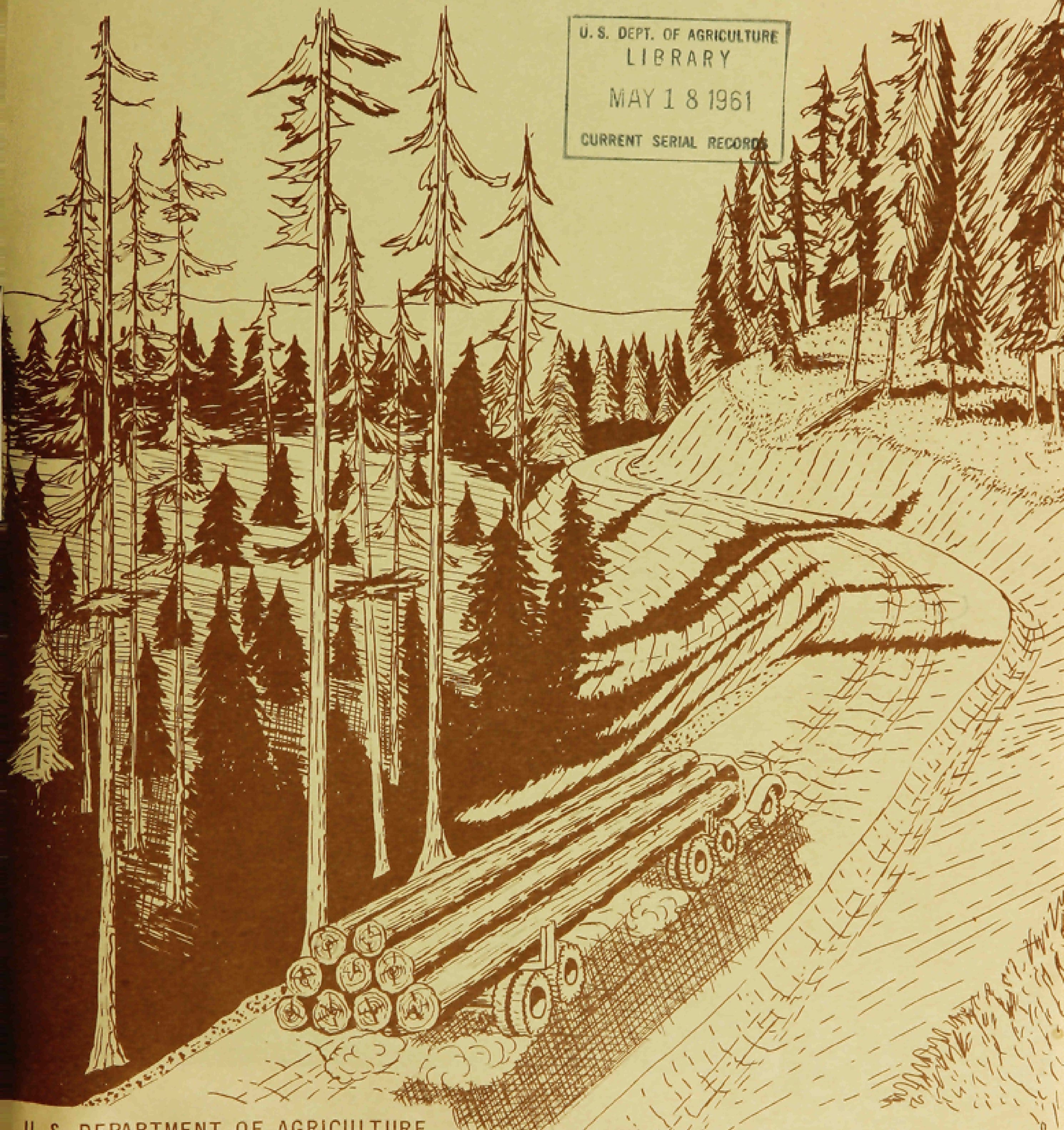
LOGGING ROAD HANDBOOK

THE EFFECT OF ROAD DESIGN ON HAULING COSTS



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Issued December, 1960

Logging Road Handbook: The Effect of Road Design on Hauling Costs

By James J. Byrne, *Director, Division of Forest Products Research*, Roger J. Nelson, *Chief, Roads and Trails Section, Pacific Northwest Region*, and Paul H. Googins, *Civil Engineer, California Region, Forest Service.*

INTRODUCTION

This handbook is written for the use of logging road engineers and logging engineers in estimating the effect of road geometry and surface on the cost of hauling logs by motortruck and trailer. The data provided will help the road designer to evaluate alternative designs in terms of the cost of hauling logs. The factors included may also be used to estimate hauling cost on roads already constructed.

It should be emphasized that the hauling costs given herein do not include cost of road amortization and maintenance, or taxes and fees paid in lieu of road amortization and maintenance. Some assumptions and calculations were necessarily made to supplement recorded and observed data, but the results are as accurate as can be obtained without costly experimentation that would extend over years of operation.

The original study upon which this report is based was started in March 1947 and completed by August of that year. Most of the book records of costs were for calendar year 1946. Later, in 1952, studies were made in Eastern United States for small logging trucks. To insure up-to-date basic cost data, a resurvey of operating costs for 22 commercial companies was made in Western United States in the winter of 1958–59. These costs were derived from book records for calendar year 1957. As expected, the basic differences between 1947 and 1957 were found to be higher recent costs. An exception is the unit tire cost which, on a cost-per-mile basis, is lower than for 1947. This difference is probably due to the present general use of better tires that have a prolonged life and to the shortage of tires that existed during the original study.

The type of equipment observed was the conventional truck and trailer combination that is used for hauling logs (fig. 1). Such equipment has a carrying capacity that ranges from 28,400 pounds gross vehicle weight to approximately 207,000 pounds (table 1).

TABLE 1.—*Size of truck and trailer units, by gross vehicle weight, Eastern and Western United States*

G.v.w. (pounds)	Rated engine	Average light weight	Tires		Maximum load [1]	
	Hp.	*Pounds*	*Size*	*Number*	*Pounds*	*M bd. ft.*
Eastern United States: 28,400 to 34,700	100 to 135	10, 000	8.25 x 20	10	18, 400	1. 84
		12, 000	9.00 x 20	10	27, 700	2. 27
Western United States:						
50,000 to 60,000	146 to 200	17, 000	9 x 20	14	43, 000	5. 40
60,000 to 86,000	150 to 252	22, 000	10 x 20	18	46, 400	5. 80
		23, 100	10 x 22	18	54, 800	6. 97
86,000 to 103,000	185 to 265	26, 000	11 x 22	18	68, 800	8. 60
		28, 000	11 x 24	18	68, 800	
103,000 to 122,000	200 to 300	42, 000	12 x 24	18	80, 000	10. 07
122,000 to 164,000	265 to 300	48, 000	12 x 24	2	112, 000	14. 00
			14 x 24	16		
164,000 to 207,000	300 to 360	61, 000	12 x 24	2	146, 000	18. 20
			14 x 24	8		
			16 x 24	8		

[1] Maximum loads in Eastern United States figured on basis of 10 pounds per board foot of logs, and in the Western United States on basis of 8 pounds.

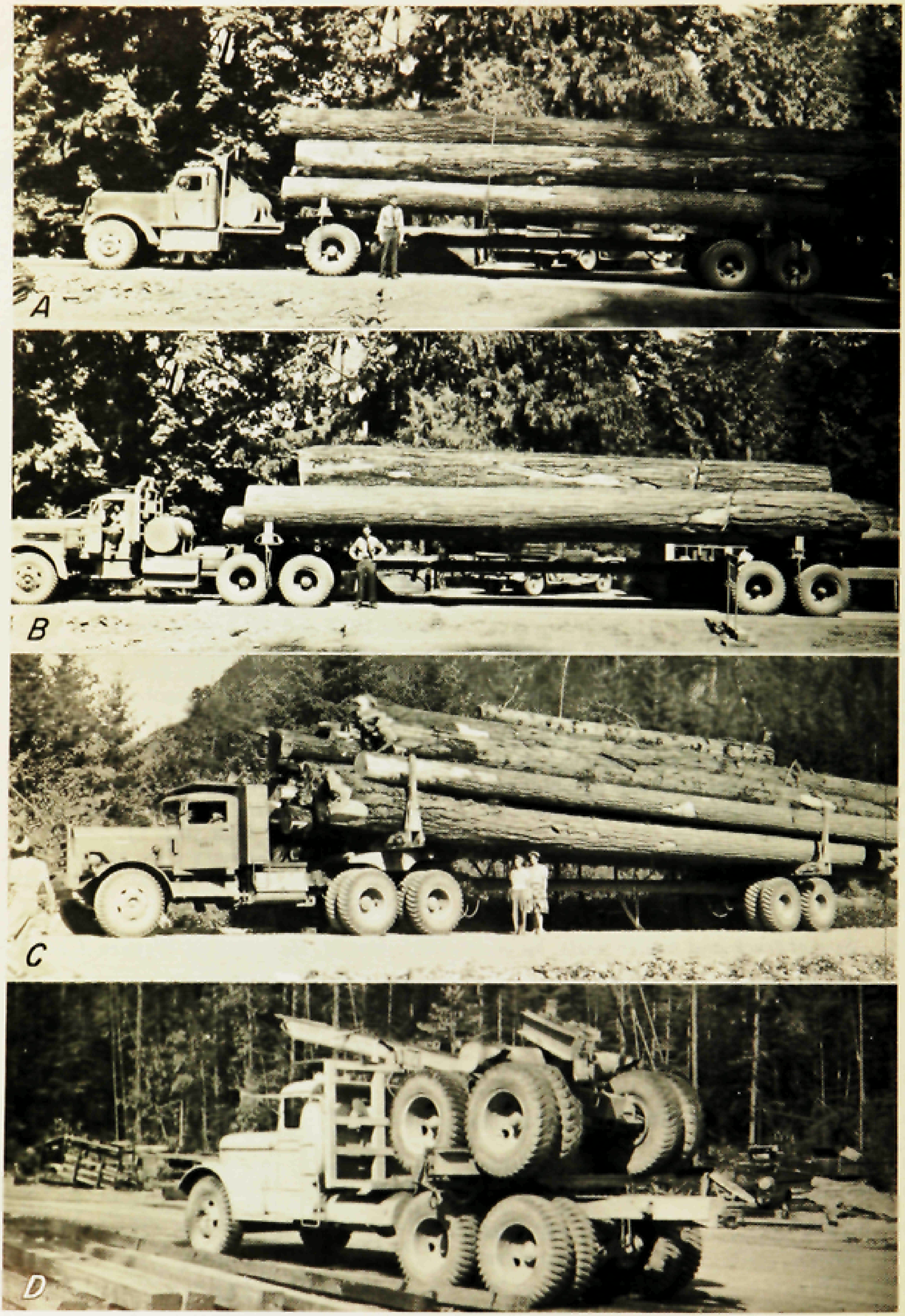

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FIGURE 1.—Truck and trailer: *A*, Single-axle drive; *B*, double-axle drive; *C*, 16-foot bunks, 25 M bd. ft. load; *D*, trailer mounted on truck for return trip.

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FIGURE 2.—Typical gravel-surfaced logging roads.

As a basis for time of travel estimates, tests were conducted to obtain data on the operation of trucks and trailers over paved, gravel-surfaced, and dirt roads. The effects of roadway widths and design were observed. Figure 2 shows two logging roads with well-consolidated surfaces. They are typical of roads upon which on-the-ground measurements were made.

Loads were weighed either with portable scale or fixed platform scales. A maximum speed of 45 miles an hour was used in calculations for loaded trucks, and 50 miles an hour for empty ones. This speed is consistent with present logging truck operation and highway speed limits. Because fuel consumption could be calculated with good accuracy, only one detailed measurement was made.

The results of this study are believed to be reasonably accurate, the degree of accuracy being dependent upon the validity of assumptions made in extending the available cost data. Probably the greatest chance for error is in maintenance costs, because there was no data on the effect of extremely steep grades on such costs. Curves, graphs, and tables that can be used in determining the cost of hauling logs are presented in the main body of this report. Details of their derivation will be found in the appendix.

SIZE OF TRUCK AND PAYLOAD

The size of truck and trailer units classified by gross vehicle weights are shown in table 1. Table 1 also shows the estimated maximum loads of timber that can be carried, based on weights of gross board feet of logs of 10 pounds and 8 pounds, respectively, for Eastern and Western conditions.

Actually, the weight of logs varies greatly by species and by size of logs as well as by the method of scaling. Unfortunately, data on log weights are not complete. Technical Note No. 218 of the Forest Products Laboratory, Madison, Wis., shows a theoretical approach toward determining weights of timber of various woods grown in the United States. Weights obtained by this method may not represent an average value for all localities, since the method is only approximate.

The density of timber of a species varies from one area to another, between trees, and within trees. Table 2 shows suggested values of unit log weights for certain Eastern and Western species. These should only be used in the absence of more reliable local data. The table also shows some variations actually measured in connection with logging studies.

TABLE 2.—*Weight of certain Eastern and Western species per board foot of green logs, including bark*

Species	Range in weight [1]	Suggested estimating weight
	Pounds	*Pounds*
Ash, white		10. 0
Birch		10. 0
Cedar (except Port Orford)	6. 0– 9. 0	8. 0
Cedar, Port Orford	6. 0–10. 3	10. 0
Cherry, black		8. 0
Douglas-fir	5. 5–13. 5	8. 0
Fir (all species)	8. 6–10. 0	9. 0
Hemlock (all species)	8. 4–11. 8	10. 0
Larch (all species)	6. 5–10. 0	8. 0
Maple, sugar		10. 0
Oak (all species)		10. 0
Pine, lodgepole		8. 0
Pine, ponderosa	6. 5–11. 5	8. 0
Pine, southern		8. 0
Pine, sugar	7. 0–11. 5	10. 0
Poplar (all species)		6. 5
Redwood	5. 0–19. 5	10. 0
Spruce (all)	5. 0– 7. 5	6. 5

[1] Some of these weights were obtained in the study reported here, and others were obtained by the State of Oregon and the Hammond Lumber Co.

TRAVEL TIME FACTORS

Travel time is influenced by grade, nature of road surface, alinement, width of roadway, sight distance, and psychological factors. In addition, it is affected by the ratio of effective engine horsepower to gross vehicle weight.

Figures 3 to 8, inclusive, show the travel time for loaded and empty trucks over paved, graveled, and dirt surfaces as influenced by grade. In these figures, the travel time is correlated with a factor B,[1] which is found from the following equation:

$$B=\frac{(HP)\times E\times 1{,}000}{GVW}$$

where

HP=Rated horsepower of engine

E=Ratio of effective horsepower to rated horsepower (from table 3), and

GVW=Gross vehicle weight in pounds, weight of vehicle plus load, if any

The speed over concrete paved roads will not be significantly different than over good asphalt paved roads.

A dirt surface is considered suitable for average speed if occasional rough spots appear where native rock projects, and if its bed is slightly less firm than a graveled surface. A softer road surface would decrease the speed considerably.

The gravel surface is taken as a well-bound surface with a solid roadbed, not springy under traffic.

TABLE 3.—*Ratio (E) of effective horsepower to rated horsepower at various elevations*

Elevation above sea level (feet)	Engine horsepower output	Value of E
	Percent	
	100	0.74
1,000	97	.72
2,000	94	.70
3,000	91	.68
4,000	88	.66
5,000	85	.63
6,000	82	.61

[1] A list of the symbols and abbreviations used in this report is given on p. 44.

Figure 9 is included to show the average delay time per M board feet for various sizes of payload. This delay time does not include that occasioned by road design, such as spacing of turnouts. It does include time for loading, unloading, waiting for loads and unloader, fueling up, and filling the water tank.

Figures 10 through 13 have been provided to show the effect of curvature on travel time over roads of various widths.

In using the time graphs (figs. 3–13), it is necessary to divide the road into sections according to grade. First determine whether the speed for loaded trucks is governed by grade or curvature in the section considered. The greater time governs. Then repeat the process for the returning empty truck. The round-trip time per mile is the sum of these two governing time factors. The round-trip time for the section is the product of the section length in miles and the combined round-trip time.

Figures 14 and 15 show the approximate speeds obtained as controlled by curvature and grade on logging roads. These figures are valuable to the road designer in that there is nothing to be gained in improving alinement to provide higher speed if the speed is already controlled by grade.

The effect of turnout spacing and density of traffic on travel time over single-lane and lane-and-one-half roads is shown in figure 16. It should be noted that the percentage increase in travel time is applied only to empty trucks. Loaded trucks are assumed to have the right-of-way. If traffic and road design are uniform, the percentage shown in the graph can be applied to the total time. Otherwise the road must be divided into sections, according to traffic density and turnout spacing, and time determined separately for each section.

The foregoing method is applicable to roads with grades of a sustained, not rolling, nature. Rolling grade complicates the figuring of time and requires more refinement than is needed for sustained grades. Deceleration and acceleration of the vehicle play an important part in speed over rolling grades.

Figure 17 shows the distance required, according to grade, for a loaded truck to accelerate and decelerate from one speed to another.

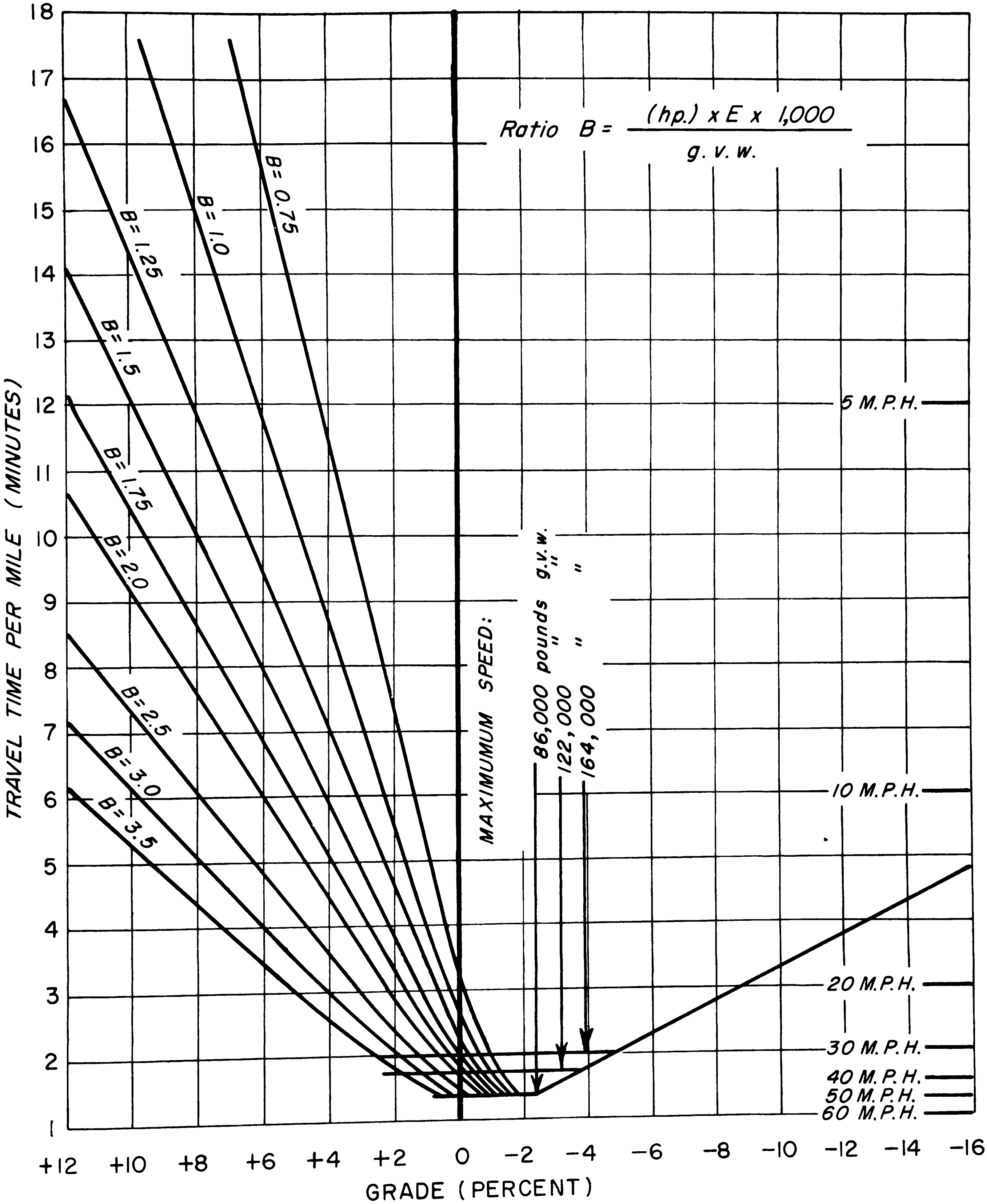

FIGURE 3.—Effect of grade on travel time—loaded trucks, asphalt paved roads (R=0.013).

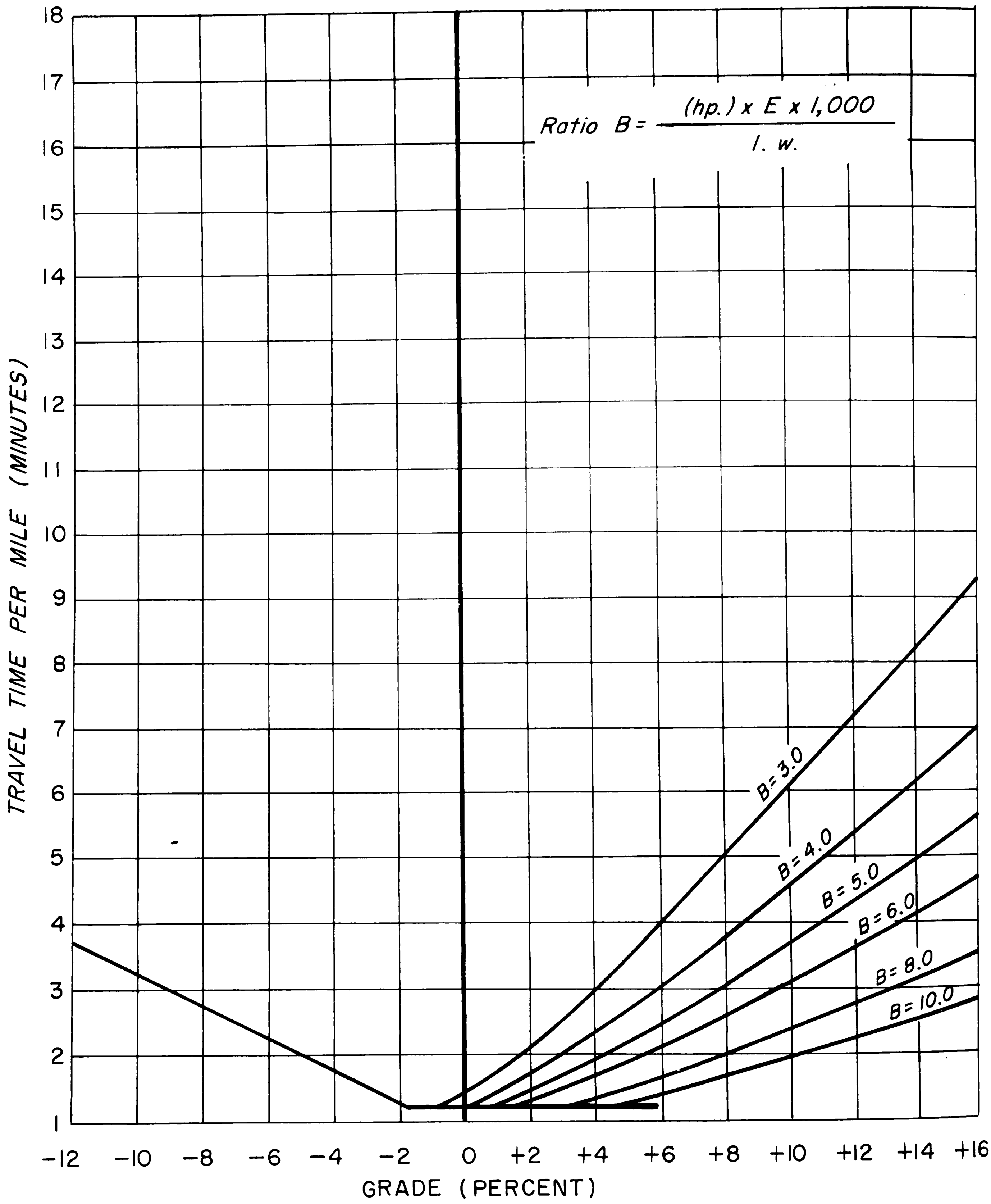

FIGURE 4.—Effect of grade on travel time—empty trucks, asphalt paved roads (R=0.013).

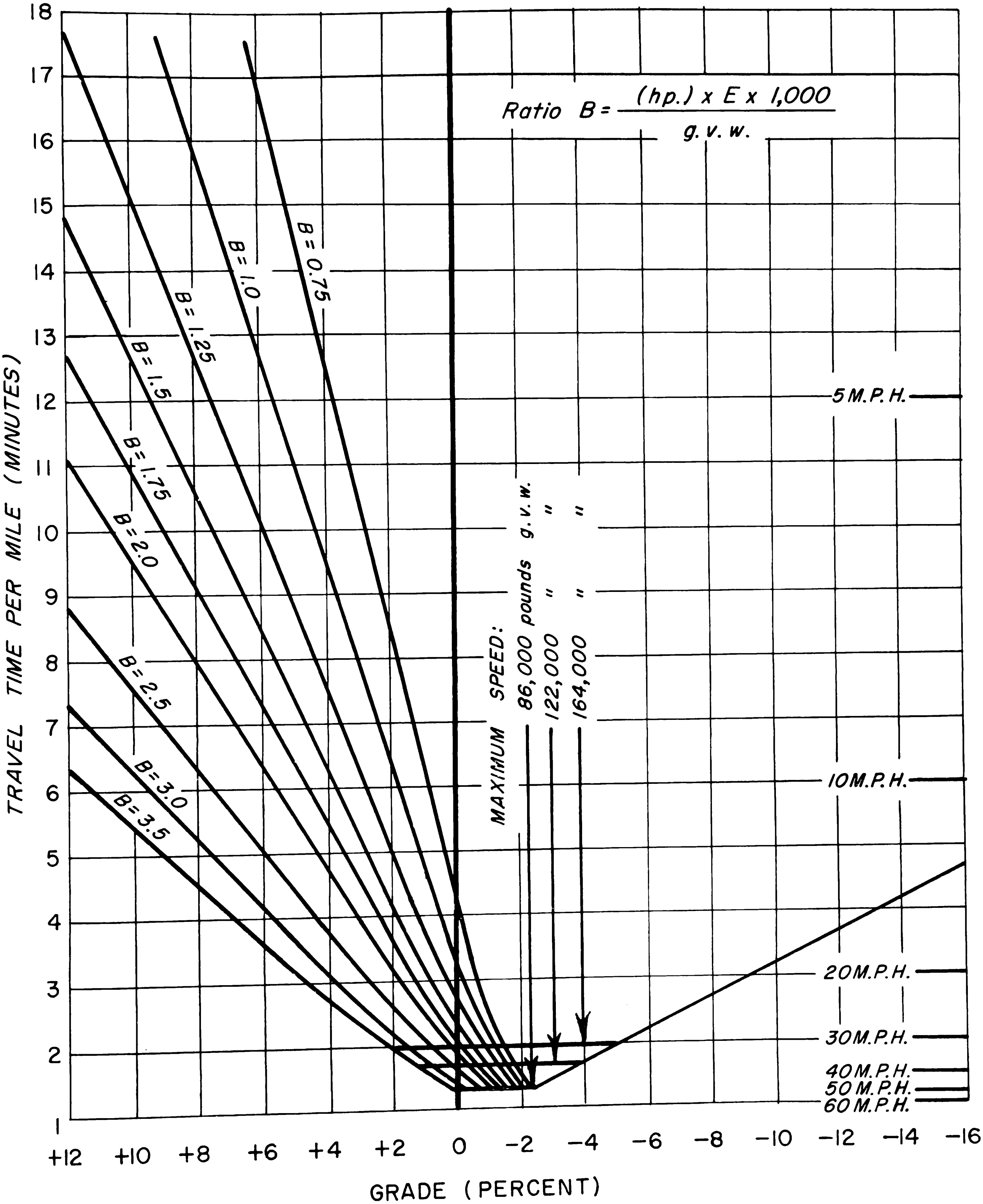

FIGURE 5.—Effect of grade on travel time—loaded trucks, compacted gravel roads (R=0.018).

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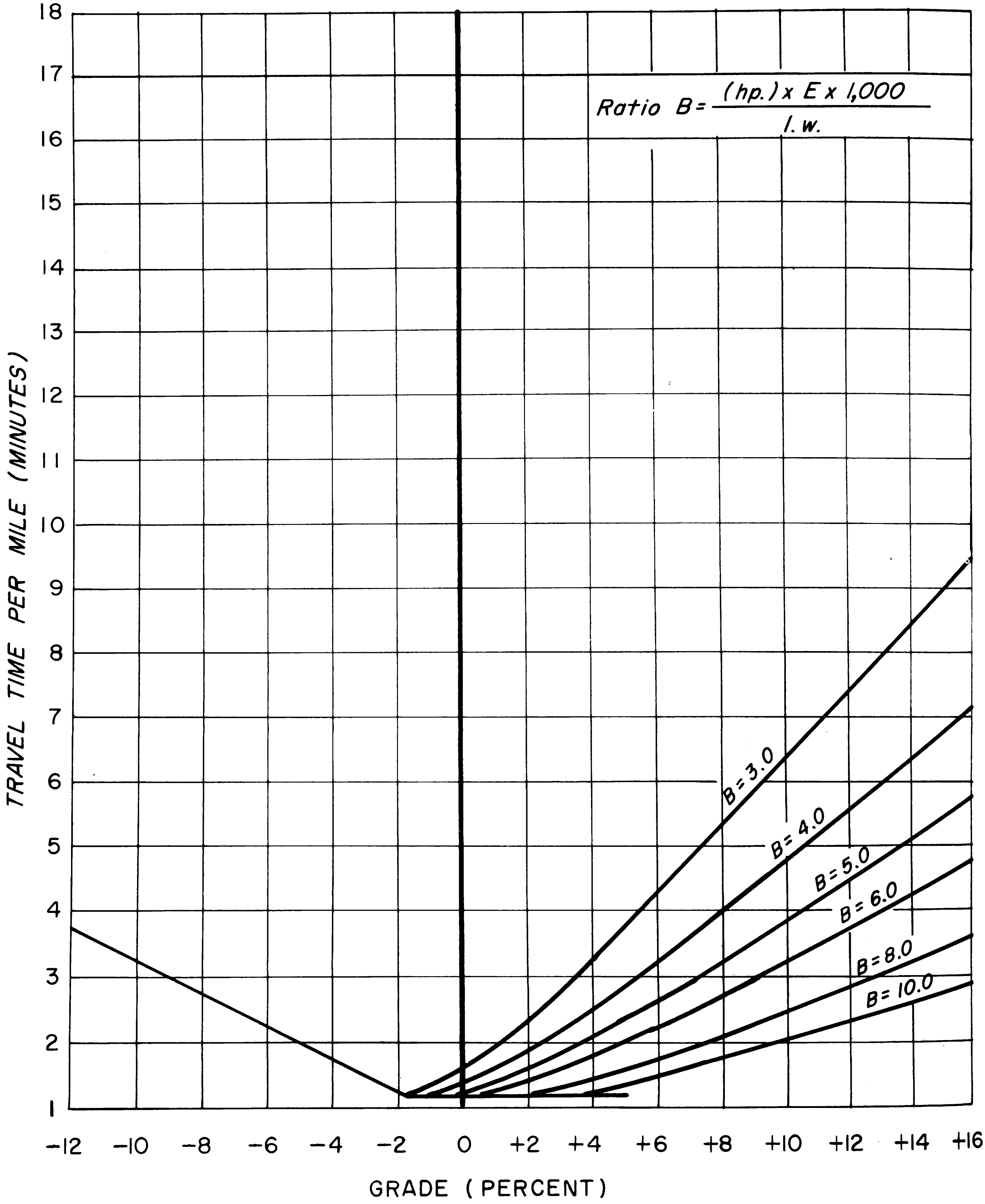

FIGURE 6.—Effect of grade on travel time—empty trucks, compacted gravel roads (R=0.018).

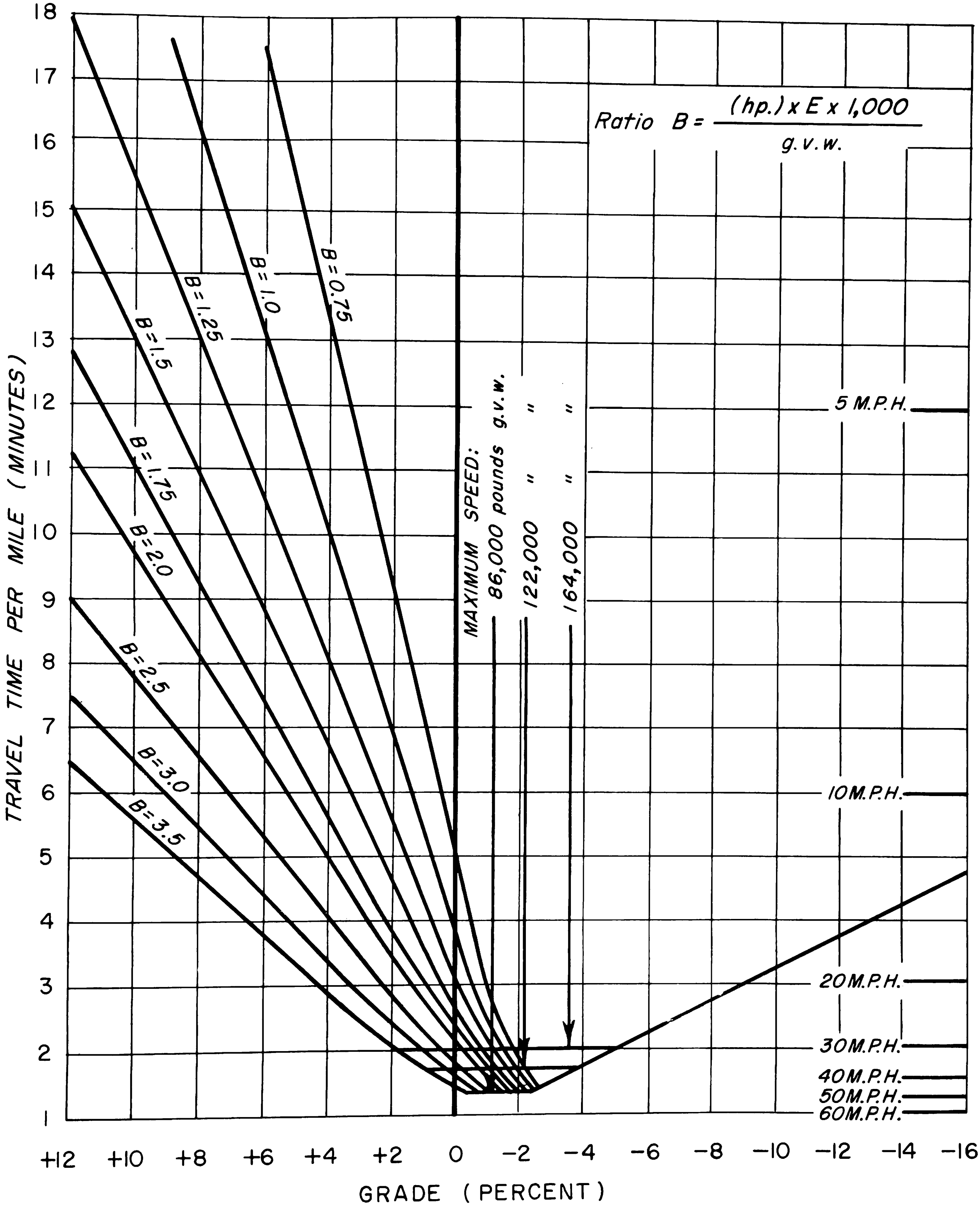

FIGURE 7.—Effect of grade on travel time—loaded trucks, dirt roads (R=0.022).

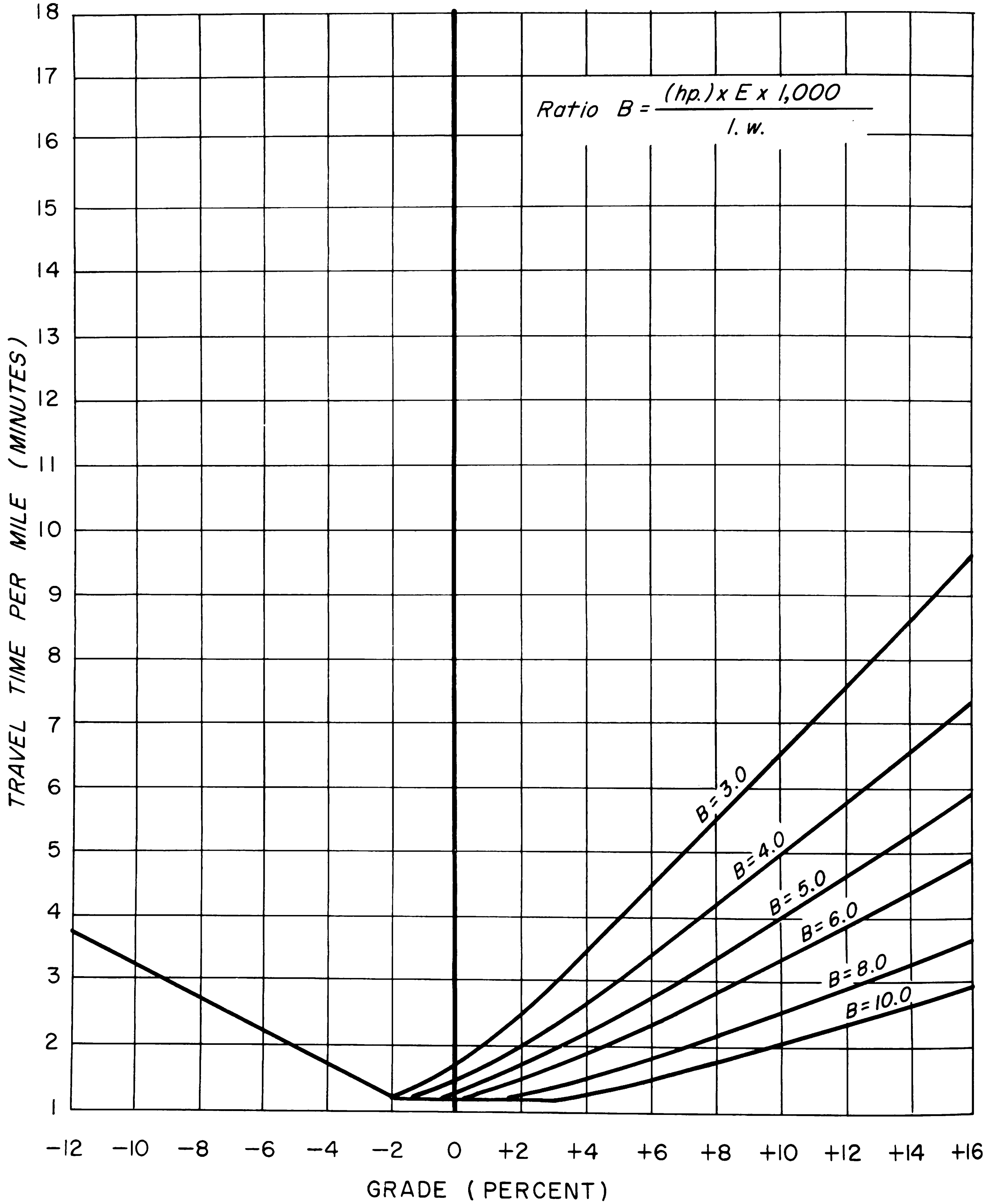

FIGURE 8.—Effect of grade on travel time—empty trucks, dirt roads (R=0.022).

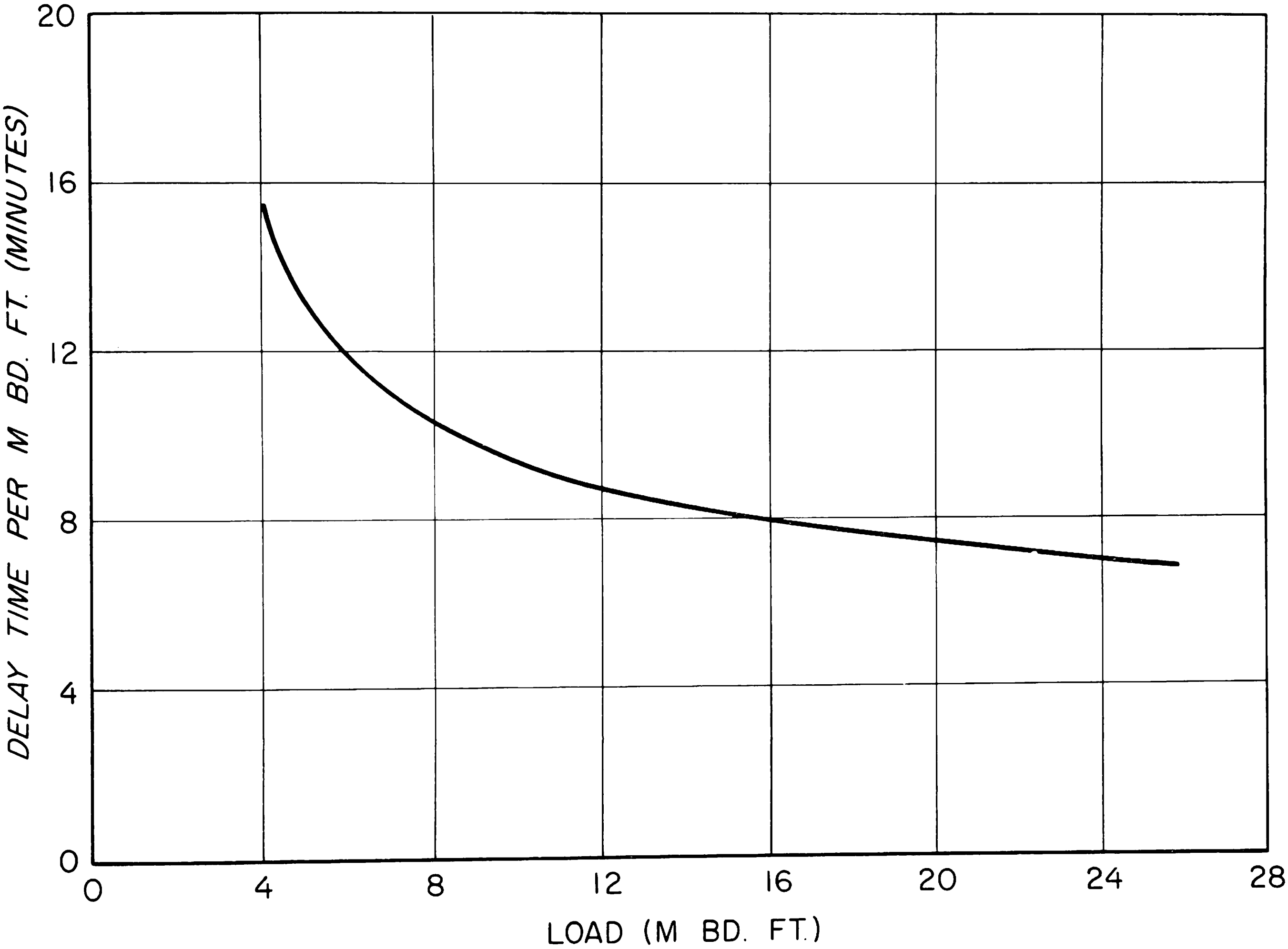

FIGURE 9.—Delay time per round trip, not including delays due to road design.

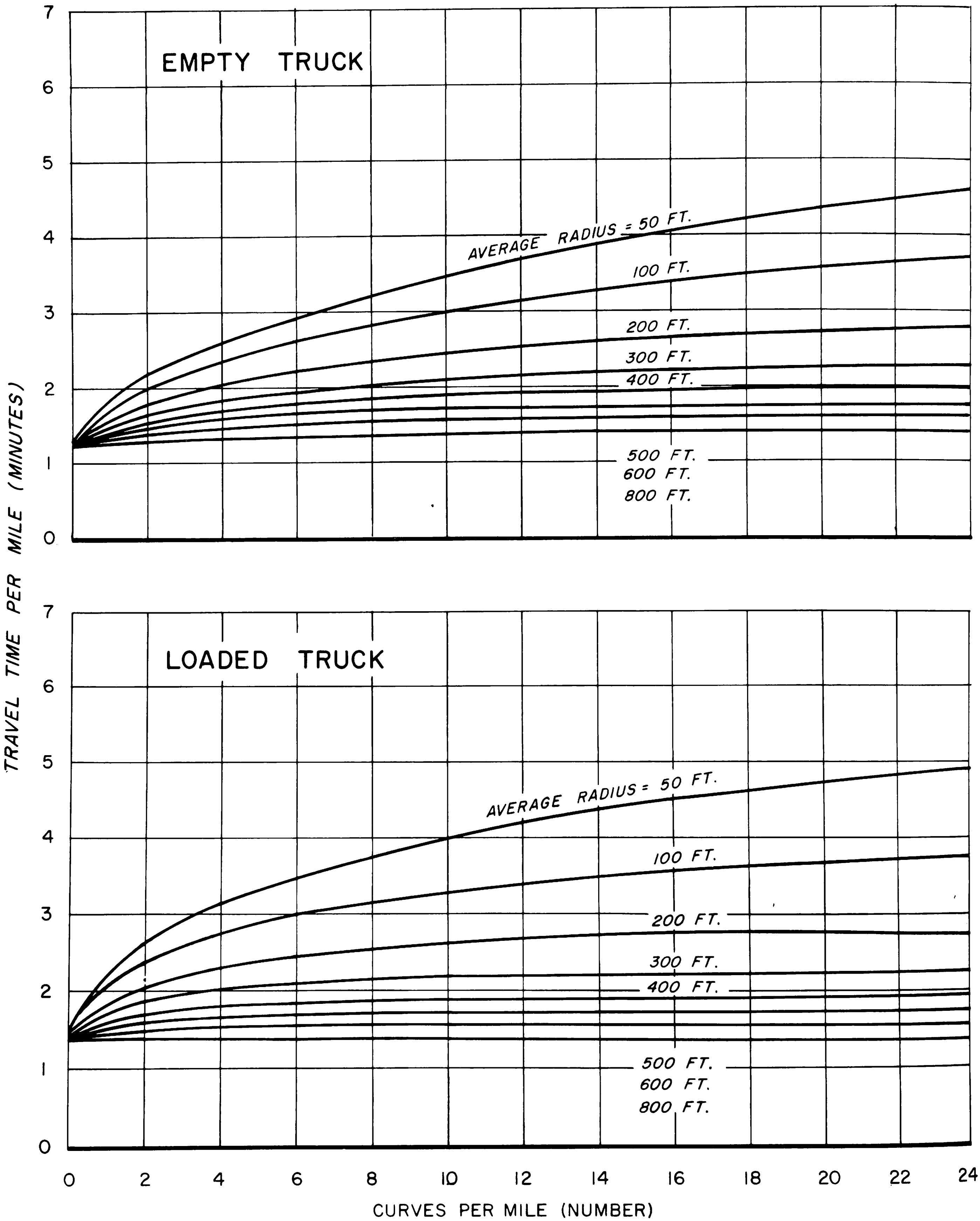

FIGURE 10.—Effect of curvature on travel time—double-lane roads.

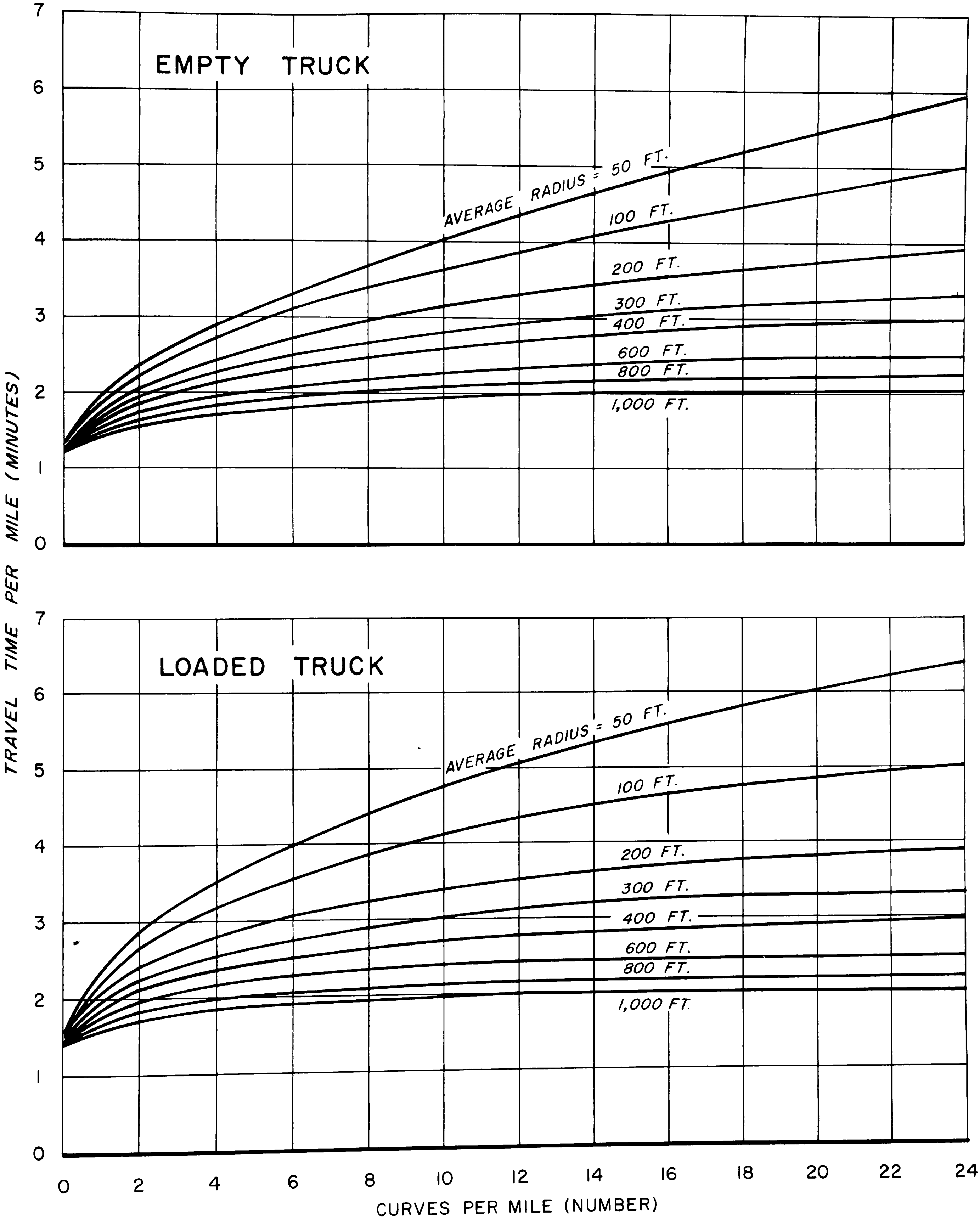

FIGURE 11.—Effect of curvature on travel time—lane-and-one-half roads.

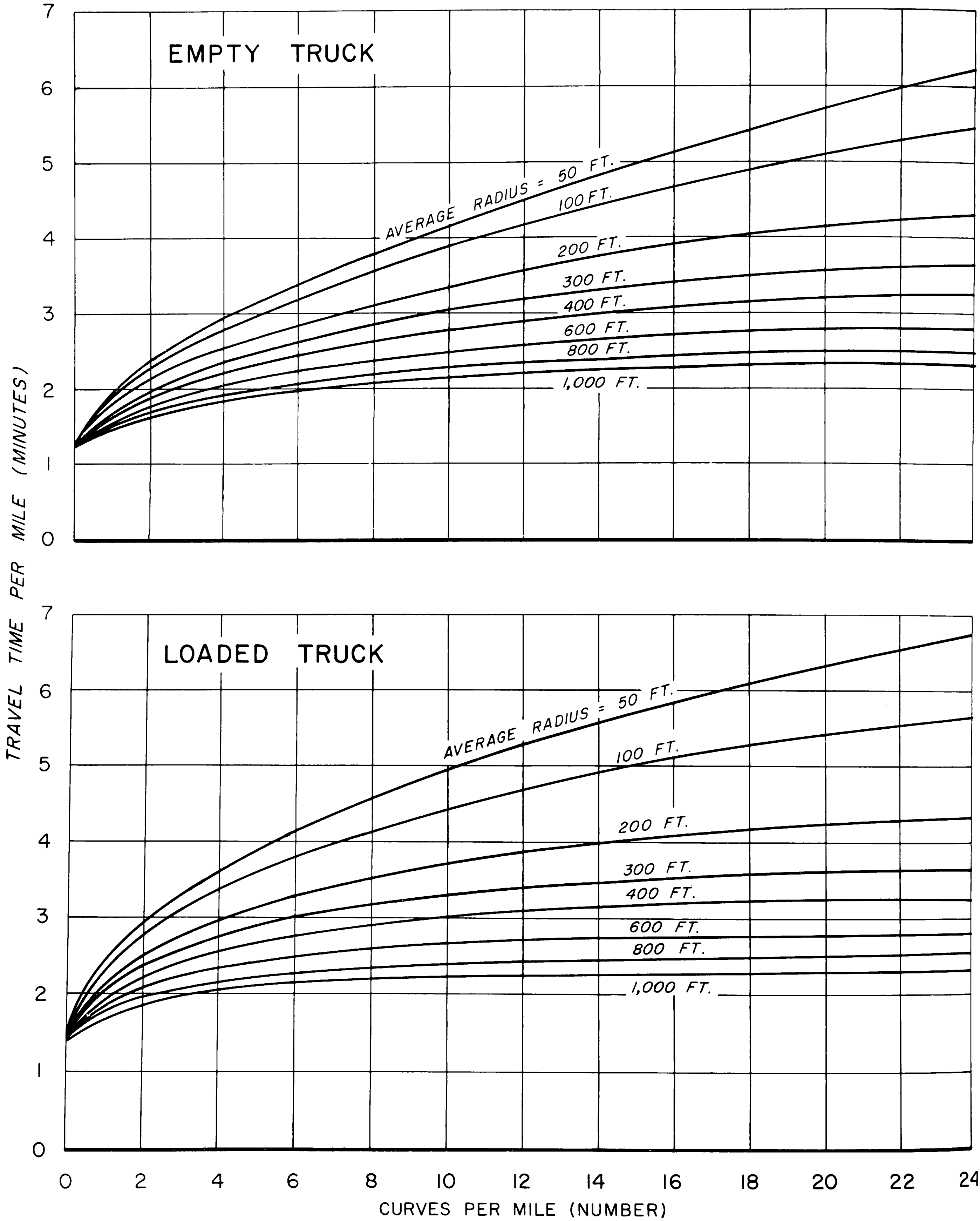

FIGURE 12.—Effect of curvature on travel time—single-lane roads with ditch.

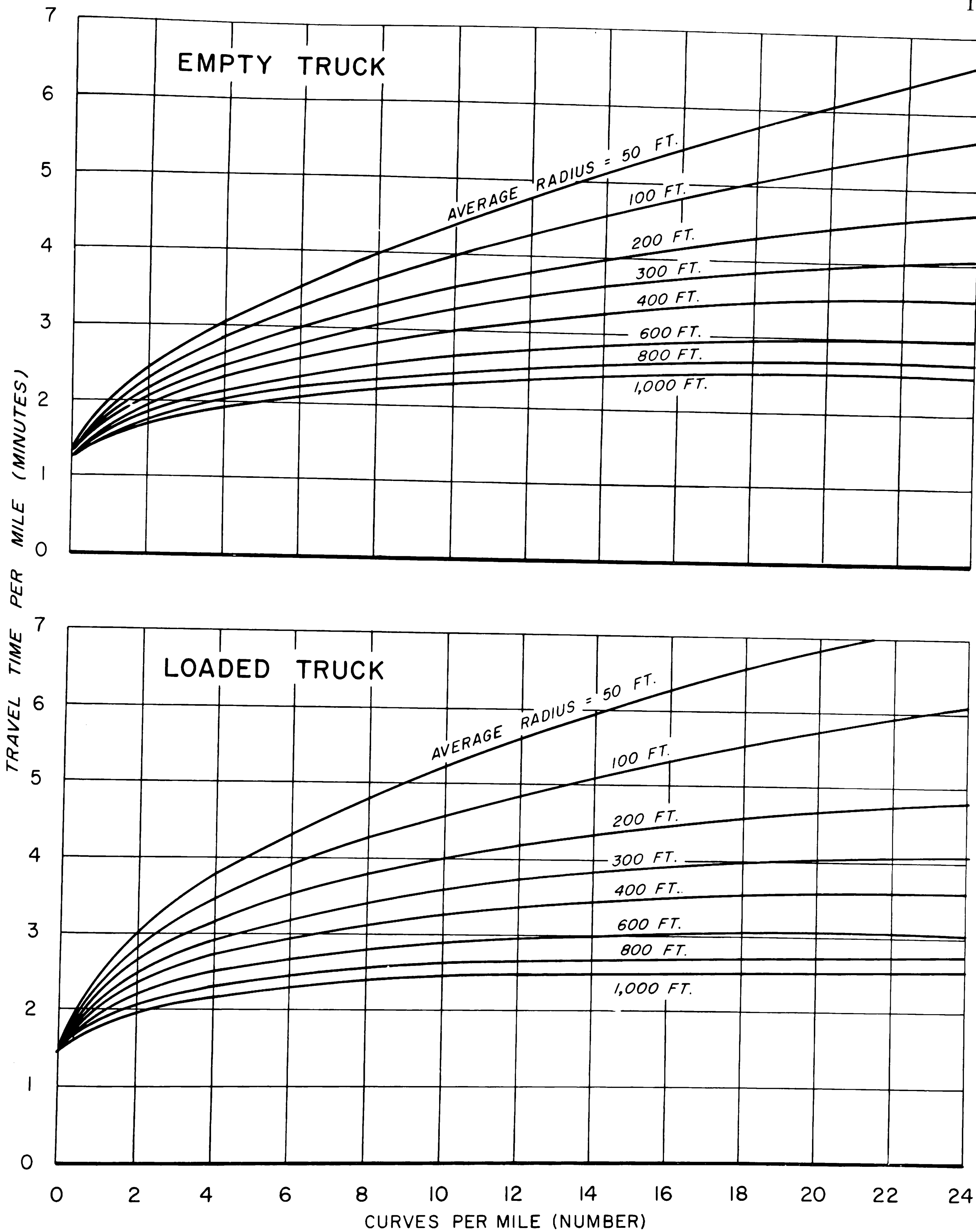

FIGURE 13.—Effect of curvature on travel time—single-lane roads without ditch.

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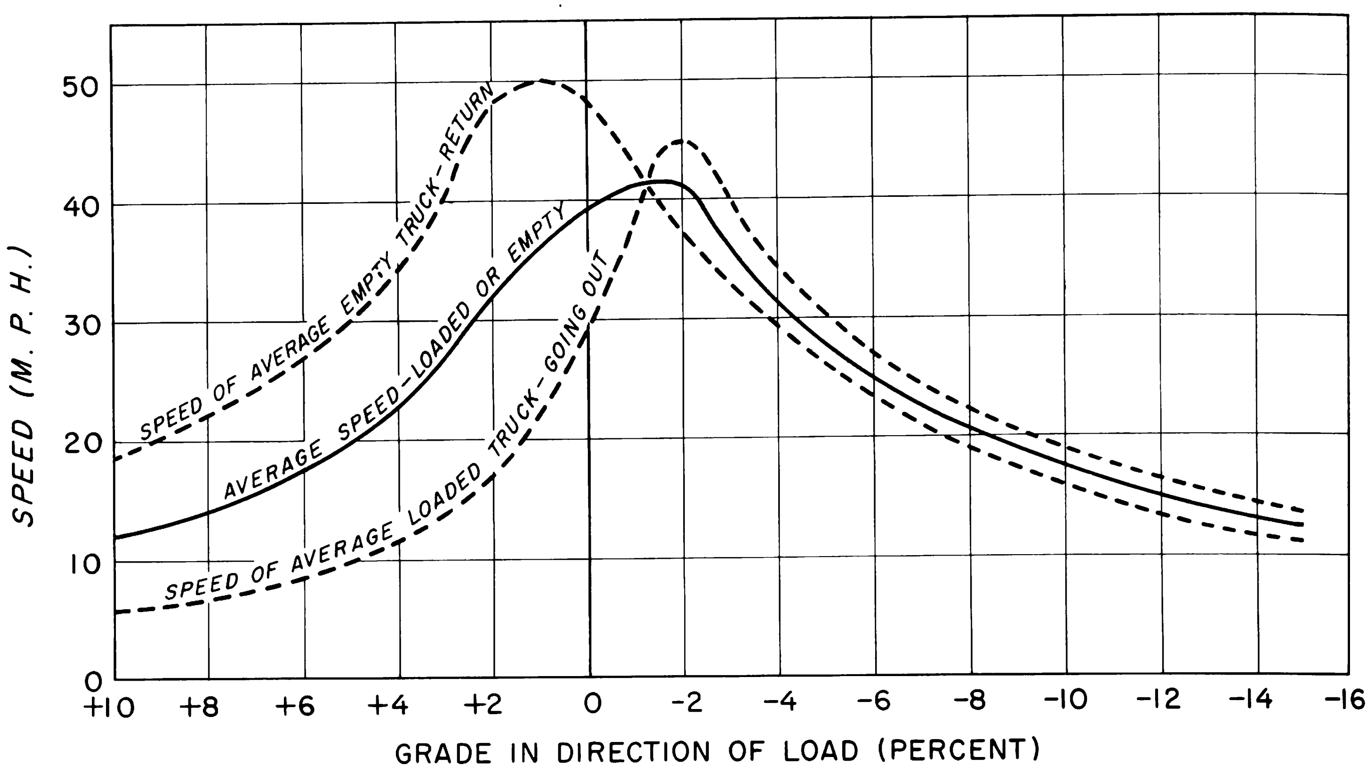


FIGURE 14.—Speeds of average logging truck on grades where speed is not controlled by alinement—gravel roads. (B=1.75 for loaded trucks and 5.0 for empty.)

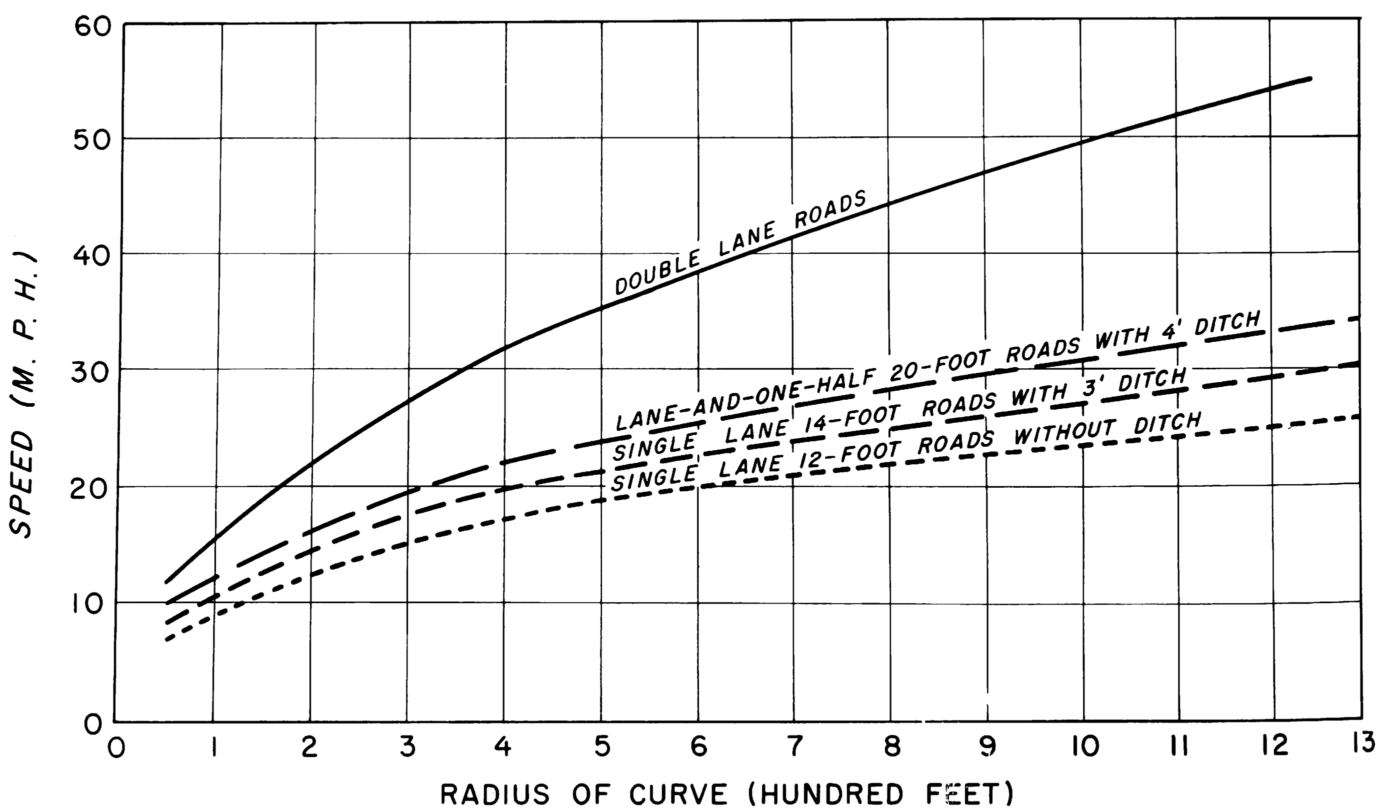


FIGURE 15.—Speeds of average logging truck on curves where speed is not controlled by grade.

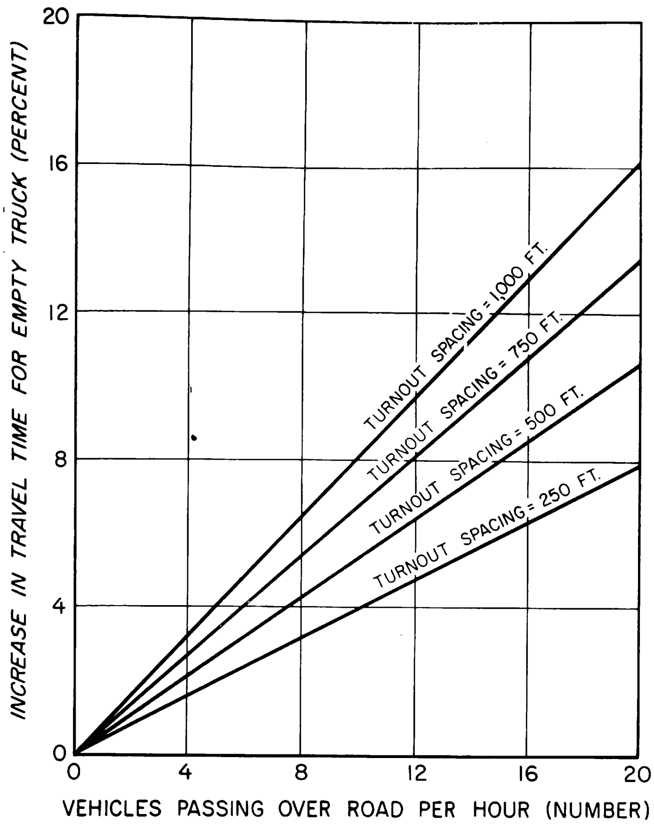


FIGURE 16—Effect of turnout spacing and density of traffic on travel time of empty trucks over single-lane and lane-and-one-half roads.

Example 1. Time of Haul on Sustained Grades

In this example the problem is to find the time of travel of a 66,000 g.v.w., 165-hp. truck and trailer traveling over single-lane gravel road with ditch at 2,000-foot average elevation. The traffic density is 20 vehicles per hour, and the turnout spacing is 1,000 feet. Grades and alinement for sections of the road are as follows:

Section	Grade [1]	Distance	Curves	Curve radius
	Percent	*Miles*	*Number*	*Feet*
1	+10	0. 20	1	100
2	+6	. 35	1	300
			1	300
3	−2	21. 00	20	150
			30	300
			40	400
			20	500
4	−10	. 25	1	100
			1	300
5	−6	1. 10	2	200
			3	300
			2	400

[1] Grade is indicated in the direction of travel with the load.

Since this is a single-lane gravel road, figures 5 and 6 (pp. 7–8) are used to determine the time as affected by grade:

$$B=\frac{hp\times E\times 1{,}000}{gvw}$$

where

$E=0.70$ for 2,000-foot elevation (see table 2, p. 3)

$$B\ (\text{loaded})=\frac{165\times 0.70\times 1{,}000}{66{,}000}=1.75$$

From table 1 (p. 1) we find that the empty weight of truck is 22,000 pounds. Therefore:

$$B\ (\text{empty})=\frac{165\times 0.70\times 1{,}000}{22{,}000}=5.25$$

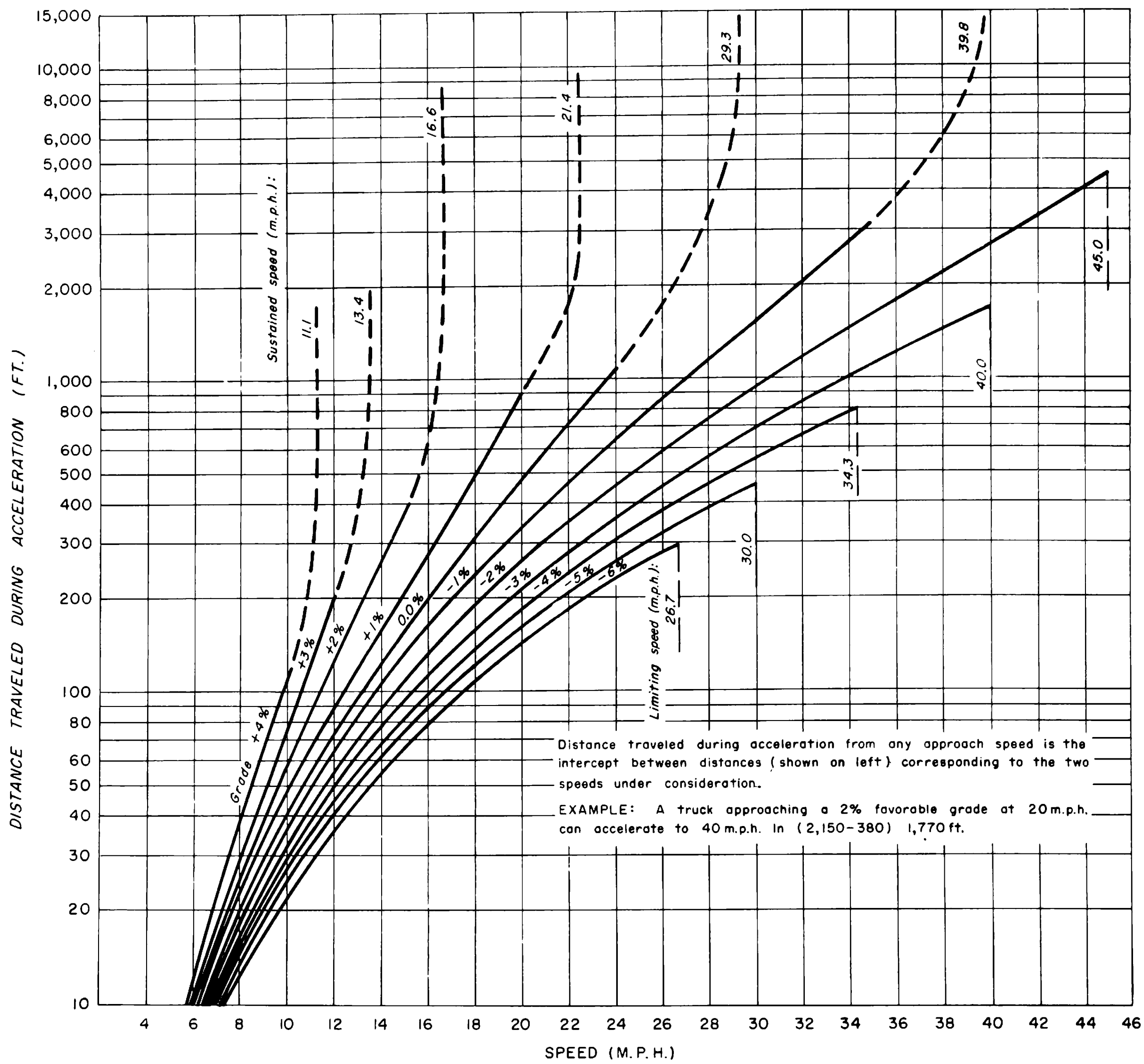
With the values of B (loaded) and B (empty), the time corresponding to each grade is found from figures 5 and 6 for loaded and empty trucks, respectively. These are entered in the following tabulations:

Section	Time per mile— As controlled by grade: Loaded truck	Time per mile— As controlled by grade: Unloaded truck	Time per mile— As controlled by alinement: Loaded truck	Time per mile— As controlled by alinement: Unloaded truck
	Minutes	*Minutes*	*Minutes*	*Minutes*
1	[1] 10. 90	[1] 3. 25	3. 57	2. 98
2	[1] 7. 20	2. 25	2. 92	[1] 2. 53
3	1. 33	1. 52	[1] 2. 75	[1] 2. 45
4	3. 24	[1] 3. 70	[1] 3. 48	3. 08
5	2. 25	2. 50	[1] 3. 00	[1] 2. 63

[1] Denotes governing time for the section—loaded and unloaded.

Section	Governing unloaded time × 1.162	Total time per round-trip mile	Distance	Time per section
		Minutes	*Miles*	*Minutes*
1	3. 77	14. 67	0. 20	2. 93
2	2. 94	10. 14	. 35	3. 55
3	2. 85	5. 60	21. 00	117. 60
4	4. 30	7. 78	. 25	1. 95
5	3. 06	6. 06	1. 10	6. 67
Total			22. 90	132. 70

Where grade is not the governing condition affecting speed, the effect of alinement is then determined from figure 12, p. 14. An example of



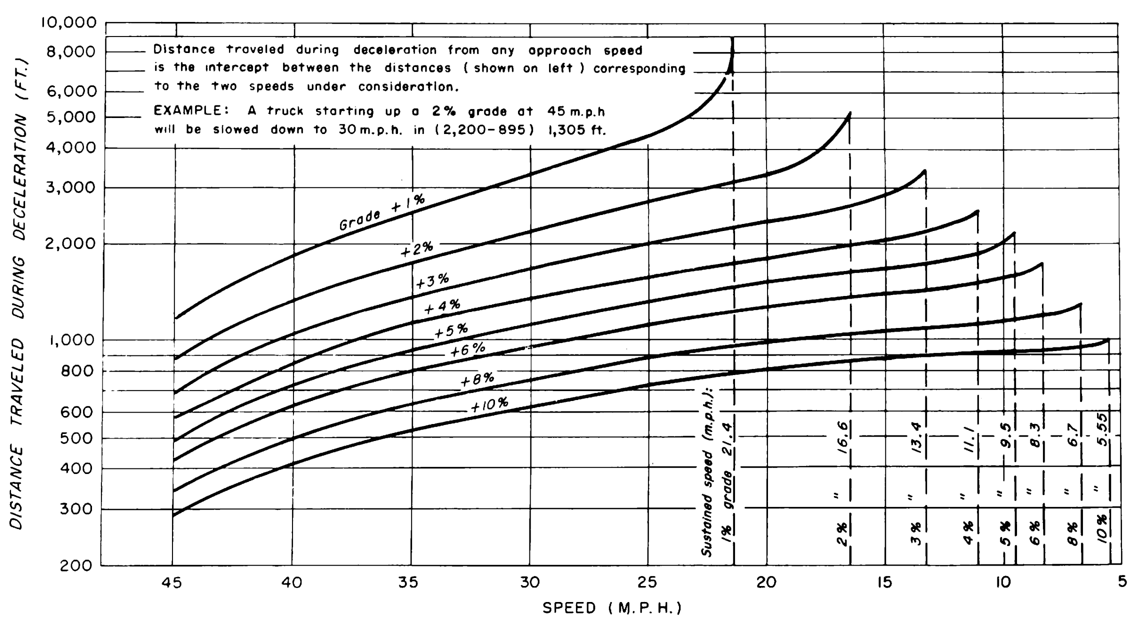


FIGURE 17.—Accelerating and decelerating distances for a loaded truck traveling over a crushed-gravel surface. ($B=1.75$.)

how the average radius is obtained is shown below for Section 3:

$$r=\frac{(20\times150)+(30\times300)+(40\times400)+(20\times500)}{20+30+40+20}=346 \text{ ft.}$$

The number of curves per mile for this section is:

$$\frac{20+30+40+20}{21}=5.24$$

The speeds corresponding to these values for Section 3 are found to be 2.75 and 2.45 minutes for loaded and unloaded trucks, respectively. In a similar manner, values are determined for other sections and entered in the foregoing tabulations.

The effect of turnout spacing is now found from figure 16, p. 17, which shows that a 16.2 percent increase in travel time results from a turnout spacing of 1,000 feet with a traffic density of 20 vehicles per hour. Therefore the governing time for unloaded trucks, as determined on the basis of alinement and grade, must be multiplied by 1.162 to give the time unloaded for use in combining with the time loaded to find the total time per round trip mile for a section. This is indicated in the foregoing tabulations.

The total time is then found to be 132.70 minutes which, for 22.90 miles, gives an average time per round trip mile of

$$\frac{132.70}{22.90}=5.79 \text{ minutes.}$$

Example 2. Time on Grade When Truck Is Decelerating Because of Change in Grade

Assume that a road has a 600-foot long, −1-percent grade approaching a 6-percent rise. Find the speed at the top of the 6-percent rise, assuming that $B=1.75$ on a gravel road.

From figure 5, p. 7, it is found that the speed on a −1-percent grade is

$$\frac{60 \text{ minutes}}{1.5 \text{ minutes per mile}}=40 \text{ miles per hour.}$$

In figure 17, find the point where the 6-percent-grade line is intersected by the 40-mile-per-hour line; this is at 625 feet. From this point, follow the 6-percent grade line for 600 feet (the length of the grade). The point of intersection is at 1,225 feet, and the final speed indicated is 21.8 miles per hour.

The average speed while ascending the 6-percent grade is

$$\frac{40+21.8}{2}=30.9 \text{ miles per hour.}$$

Therefore, the time required to negotiate the short grade is

$$\frac{60}{30.9}\times\frac{600}{5{,}280}=0.221 \text{ minutes.}$$

Example 3. Effect of Break in Grade on Adverse Grade

From figure 17, p. 18, it is possible to compute and compare the time involved in traveling up over a summit with that involved in negotiating a uniform grade produced by cutting and filling.

As an example, consider a gravel road with a grade; it could be constructed either by leveling or by rolling the grade up over small hills, using 500 feet of adverse 4-percent grade and 400 feet of favorable 5-percent grade in order to reduce construction costs. The speed of a loaded truck on the level grade, from figure 5 (p. 7), would be 29.3 m.p.h. ($t=2.05$ minutes per mile). If the truck approaches the 4-percent adverse grade at this speed, it will be going 19.0 m.p.h. when it reaches the top (see fig. 17, bottom). If the truck is going 19.0 m.p.h. when it starts down the 5-percent favorable grade, it will be going 30.0 m.p.h. when it reaches the bottom (see fig. 17, top). The average speed going up is 24.15 m.p.h., and the average speed going down is 24.5 m.p.h. Therefore, the average speed over the entire 900 feet (adverse and favorable combined) would be 24.32 m.p.h. as compared with 29.3 if the level grade were constructed.

This method does not give exact results, because of the assumption that the rate of acceleration and deceleration is uniform throughout the acceleration and deceleration periods: actually, these rates are not uniform. However, results will be reasonably close to the actual speed.

HAULING COST BY ELEMENTS

Tables 4, 5, and 6 show the elements of hauling cost for gasoline and diesel trucks, respectively. It will be noted that these elements do not include cost of highway amortization or maintenance, or taxes and fees assessed for those purposes. Also, property taxes are not included, since they are either too small to be significant or are not charged at all.

Fixed costs are figures for a total operating period of 52 weeks per year, 5 days per week, 10 hours per day. These costs include:

(a) *Depreciation*—figured on the cost of truck and trailer, less tires—8-year life, 6-percent salvage value.

(b) *Interest*—figured at 6 percent on the cost of truck and trailer with tires.

TABLE 4.—*Hauling cost, by elements, for various sizes of gasoline truck and trailer combinations, Western United States, 1957* [1]

Item	Size of load—g.v.w. 50,000–60,000 lbs.	60,000–86,000 lbs.	86,000–103,000 lbs.	103,000–122,000 lbs.	122,000–164,000 lbs.	164,000–207,000 lbs.
FIXED COSTS PER MINUTE THROUGHOUT YEAR—10-HOUR DAY AND 5-DAY WEEK BASIS						
Depreciation	$0.0105	$0.0118	$0.0145	$0.0188	$0.0248	$0.0288
Interest	.0061	.0070	.0089	.0114	.0155	.0182
Ins., fire and theft	.0007	.0008	.0010	.0012	.0016	.0018
Ins., P.L. & D	.0013	.0013	.0013	.0013	.0013	.0013
Ins., collision	.0027	.0027	.0028	.0030	.0033	.0034
Total	.0213	.0236	.0285	.0357	.0465	.0535
OPERATING COSTS PER MINUTE DRIVING TIME						
Fuel [2]	$0.0195	$0.0285	$0.0367	$0.0440	$0.0560	$0.0727
Lubrication	.0027	.0036	.0047	.0056	.0072	.0094
Repairs	.0559	.0869	.1017	.1246	.1532	.1745
Total	.0781	.1190	.1431	.1742	.2164	.2566
DEPENDENT COST PER MINUTE DRIVING TIME PLUS DELAY TIME						
Driver's wage, including annual leave	$0.0438	$0.0438	$0.0438	$0.0438	$0.0438	$0.0438
Social security tax	.0007	.0007	.0007	.0007	.0007	.0007
Unemployment compensation	.0011	.0011	.0011	.0011	.0011	.0011
Administration	.0085	.0085	.0085	.0085	.0085	.0085
Industrial insurance	.0049	.0049	.0049	.0049	.0049	.0049
Total	.0590	.0590	.0590	.0590	.0590	.0590
TIRE COST PER MILE						
Pavement	$0.0256	$0.0310	$0.0420	$0.0498	$0.0813	$0.0974
Gravel	.0776	.0940	.1274	.1512	.2467	.2953
Dirt	.1239	.1500	.2033	.2412	.3940	.4712

[1] Highway use fees, such as P.U.C. fees, fuel taxes, etc., are not included as part of hauling cost.
[2] Cost of gasoline without State tax: $0.222 per gallon.

TABLE 5.—*Hauling cost, by elements, for various sizes of diesel truck and trailer combinations, Western United States, 1957* [1]

FIXED COSTS PER MINUTE THROUGHOUT YEAR—10-HOUR DAY AND 5-DAY WEEK BASIS

Item	Size of load—g.v.w.					
	50,000–60,000 lbs.	60,000–86,000 lbs.	86,000–103,000 lbs.	103,000–122,000 lbs.	122,000–164,000 lbs.	164,000–207,000 lbs.
Depreciation	----------	$0. 0163	$0. 0191	$0. 0234	$0. 0287	$0. 0327
Interest	----------	. 0093	. 0112	. 0137	. 0178	. 0207
Insurance, fire and theft	----------	. 0013	. 0015	. 0018	. 0022	. 0025
Insurance, P.L. and D	----------	. 0013	. 0013	. 0013	. 0013	. 0013
Insurance, collision	----------	. 0029	. 0030	. 0032	. 0034	. 0036
Total	----------	. 0298	. 0361	. 0434	. 0534	. 0608

OPERATING COST PER MINUTE DRIVING TIME

Item	50,000–60,000 lbs.	60,000–86,000 lbs.	86,000–103,000 lbs.	103,000–122,000 lbs.	122,000–164,000 lbs.	164,000–207,000 lbs.
Fuel [2]	----------	$0. 0140	$0. 0182	$0. 0220	$0. 0283	$0. 0368
Lubrication	----------	. 0040	. 0053	. 0064	. 0082	. 0106
Repairs	----------	. 1022	. 1197	. 1466	. 1802	. 2053
Total	----------	. 1202	. 1432	. 1750	. 2167	. 2527

DEPENDENT COST PER MINUTE DRIVING TIME PLUS DELAY TIME

Item	50,000–60,000 lbs.	60,000–86,000 lbs.	86,000–103,000 lbs.	103,000–122,000 lbs.	122,000–164,000 lbs.	164,000–207,000 lbs.
Driver's wage, including annual leave	$0. 0438	$0. 0438	$0. 0438	$0. 0438	$0. 0438	$0. 0438
Social security tax	. 0007	. 0007	. 0007	. 0007	. 0007	. 0007
Unemployment compensation	. 0011	. 0011	. 0011	. 0011	. 0011	. 0011
Administration	. 0085	. 0085	. 0085	. 0085	. 0085	. 0085
Industrial insurance	. 0049	. 0049	. 0049	. 0049	. 0049	. 0049
Total	. 0590	. 0590	. 0590	. 0590	. 0590	. 0590

TIRE COST PER MILE

Item	50,000–60,000 lbs.	60,000–86,000 lbs.	86,000–103,000 lbs.	103,000–122,000 lbs.	122,000–164,000 lbs.	164,000–207,000 lbs.
Pavement	$0. 0256	$0. 0310	$0. 0420	$0. 0498	$0. 0813	$0. 0974
Gravel	. 0776	. 0940	. 1274	. 1512	. 2467	. 2953
Dirt	. 1239	. 1500	. 2033	. 2412	. 3940	. 4712

[1] Highway use fees such as P.U.C. fees, fuel taxes, etc., are not included as part of hauling cost.
[2] Cost of diesel fuel without State tax: $0. 16 per gallon.

TABLE 6.—*Hauling cost, by elements, for gasoline trucks, Eastern United States, 1952*

Item	Size of load—g.v.w.	
	28,400 lbs.	34,700 lbs.
FIXED COSTS PER MINUTE THROUGHOUT YEAR—11-HOUR DAY AND 5-DAY WEEK BASIS		
Depreciation, 8-year life with 6-percent salvage value	$0. 0020	$0. 0025
Interest	. 0011	. 0011
License	. 0007	. 0007
Insurance, fire and theft	. 0004	. 0005
Insurance, P.L. and D	. 0007	. 0007
Insurance, collision	. 0009	. 0009
Total	. 0058	. 0069
OPERATING COSTS PER MINUTE OF DRIVING TIME		
Fuel plus tax [1]	$0. 0121	$0. 0148
Lubrication	. 0009	. 0010
Repairs	. 0189	. 0234
Total	. 0319	. 0392
DEPENDENT COSTS PER MINUTE DRIVING PLUS DELAY TIME		
Driver cost, including leave and overtime	$0. 0238	$0. 0238
Social security	. 0004	. 0004
Unemployment compensation	. 0006	. 0006
Administration prorated	. 0047	. 0047
Industrial insurance	. 0019	. 0019
Total	. 0314	. 0314
TIRE COSTS PER MILE ONE WAY		
Paved or asphalt	$0. 0281	$0. 0337
Crushed gravel, 1″ minus	. 0704	. 0845
Coarse pit run or native rock and dirt mixture	. 0931	. 1120

[1] Cost of gasoline including tax: $0.23.

(c) *Property damage and personal liability insurance*—calculated on average fleet rates in areas of low density of population, with a coverage of $10,000/$20,000.

(d) *Fire and theft insurance*—figured on 80 percent of the average value of the unit throughout its life at fleet rate.

(e) *Collision insurance*—based on "$250 deductible" on average value of truck less trailer, at fleet rate in areas of low population density.

(f) *Property taxes* (none figured).

Dependent costs include those which occur when a truck is in operating status regardless of whether it is hauling logs or standing idle because of delays in loading, unloading, etc. These costs include driver's wages, social security tax, unemployment compensation tax, industrial insurance, vacation allowance of 2 weeks a year, and administration costs. Wages are figured at $2.32 per hour with time-and-one-half for overtime. Dependent costs are figured on a per-minute basis.

Vehicle operation costs, less tires, include fuel, lubrication, and repairs. They occur only when vehicle is moving on road. These are figured per minute.

Tire costs are figured on a per-mile unit.

HAULING COST BY SHUTDOWN, DELAY, AND OPERATING PERIOD

There are a number of methods that use cost elements in calculating total hauling cost. Regardless of the method used, it is desirable that the effect of shutdowns and delays on hauling cost be shown. Accordingly, the total cost has been broken down as follows:

(a) J=*Shutdown costs*. Costs that go on during periods when the vehicle is inoperative because of shutdowns, overhauls, and holidays. These are fixed costs only.

(b) N=*Delay time costs*. Costs that occur when vehicle is in operating status but is not hauling logs. These include fixed costs and dependent costs.

(c) C=*Vehicle operating cost, less tires*. Costs that occur when vehicle is actually hauling logs. These include fixed costs, dependent costs, and vehicle operating costs.

(d) D=*Tire cost*.

Costs J, N, and C per minute and cost D per mile are shown in tables 7, 8, and 9.

Figures 18 to 21, inclusive, show hauling cost per round trip mile, based on a summation of costs. Although these costs are for gasoline trucks, for all practical purposes they are the same for diesel trucks. To use these graphs, values for C_1, C_2, C_3, and C_4, are read directly and added. The sum is the total cost per round trip mile. To determine cost per M bd. ft. per mile or cost per ton-mile, divide sum of C_1, C_2, and C_3 values by M bd. ft. per load or tons per load, respectively.

It should be emphasized that, in most cases, hauling cost per mile of road is appreciably dependent on working season and length of haul; it is not possible to work out costs with any reasonable degree of accuracy without considering these two factors.

Example 4. Cost Per M Bd. Ft. Per Mile When Hauling Time Is Known

Using the data from Example 1, p. 17, the round trip hauling time for a 66,000-pound g.v.w. load is 5.79 minutes per mile of route. The net load is 66,000 minus 22,000, or 44,000 pounds. With hemlock weighing 10 pounds per board foot, the payload is 4.4 M. The length of haul is 22.9 miles.

Assuming an 8-month hauling season, the cost per trip (from fig. 18, bottom, p. 26) would be:

$$C_1=\$1.34$$
$$C_2=\ .28$$
$$C_3=\ .07$$
$$C_4=\ .04$$

Total cost per round trip mile=$1.73

$$\text{Cost per M bd. ft. per mile}=\frac{\$1.73}{4.4}=\$0.393$$

TABLE 7.—*Hauling cost, by periods,*[1] *for various sizes of gasoline truck and trailer combinations, Western United States, 1957*

Item	Cost per minute			Cost per mile *D*		
	J	*N*	*C*	Pavement	Gravel	Dirt
50,000 TO 60,000 POUNDS G.V.W.						
Tire cost				$0.0256	$0.0776	$0.1239
Operating cost			$0.0781			
Dependent cost		$0.0590	.0590			
Fixed cost	$0.0213	.0213	.0213			
Total	.0213	.0803	.1584	.0256	.0776	.1239
60,000 TO 86,000 POUNDS G.V.W.						
Tire cost				$0.0310	$0.0940	$0.1500
Operating cost			$0.1190			
Dependent cost		$0.0590	.0590			
Fixed cost	$0.0236	.0236	.0236			
Total	.0236	.0826	.2016	.0310	.0940	.1500
86,000 TO 103,000 POUNDS G.V.W.						
Tire cost				$0.0420	$0.1274	$0.2033
Operating cost			$0.1431			
Dependent cost		$0.0590	.0590			
Fixed cost	$0.0285	.0285	.0285			
Total	.0285	.0875	.2306	.0420	.1274	.2033
103,000 TO 122,000 POUNDS G.V.W.						
Tire cost				$0.0498	$0.1512	$0.2412
Operating cost			$0.1742			
Dependent cost		$0.0590	.0590			
Fixed cost	$0.0357	.0357	.0357			
Total	.0357	.0947	.2689	.0498	.1512	.2412
122,000 TO 164,000 POUNDS G.V.W.						
Tire cost				$0.0813	$0.2467	$0.3940
Operating cost			$0.2164			
Dependent cost		$0.0590	.0590			
Fixed cost	$0.0465	.0465	.0465			
Total	.0465	.1055	.3219	.0813	.2467	.3940
164,000 TO 207,000 POUNDS G.V.W.						
Tire cost				$0.0974	$0.2953	$0.4712
Operating cost			$0.2566			
Dependent cost		$0.0590	.0590			
Fixed cost	$0.0535	.0535	.0535			
Total	.0535	.1125	.3691	.0974	.2953	.4712

[1] *J*=Cost for period when truck is shut down due to seasonal layoff, overhaul, or other causes.
N=Cost for period when truck is in operating status but not actually hauling logs.
C=Cost for period when truck is actually hauling logs—less tires.
D=Tire cost.

TABLE 8.—*Hauling cost, by periods,*[1] *for various sizes of diesel truck and trailer combinations, Western United States, 1957*

Item	Cost per minute			Cost per mile *D*		
	J	*N*	*C*	Pavement	Gravel	Dirt
60,000 TO 86,000 POUNDS G.V.W.						
Tire cost				$0. 0310	$0. 0940	$0. 1500
Operating cost			$0. 1202			
Dependent cost		$0. 0590	. 0590			
Fixed cost	$0. 0298	. 0298	. 0298			
Total	. 0298	. 0888	. 2090	. 0310	. 0940	. 1500
86,000 TO 103,000 POUNDS G.V.W.						
Tire cost				$0. 0420	$0. 1274	$0. 2033
Operating cost			$0. 1422			
Dependent cost		$0. 0590	. 0590			
Fixed cost	$0. 0361	. 0361	. 0361			
Total	. 0361	. 0951	. 2373	. 0420	. 1274	. 2033
103,000 TO 122,000 POUNDS G.V.W.						
Tire cost				$0. 0498	$0. 1512	$0. 2412
Operating cost			$0. 1750			
Dependent cost		$0. 0590	. 0590			
Fixed cost	$0. 0434	. 0434	. 0434			
Total	. 0434	. 1024	. 2774	. 0498	. 1512	. 2412
122,000 TO 164,000 POUNDS G.V.W.						
Tire cost				$0. 0813	$0. 2467	$0. 3940
Operating cost			$0. 2167			
Dependent cost		$0. 0590	. 0590			
Fixed cost	$0. 0534	. 0534	. 0534			
Total	. 0534	. 1124	. 3291	. 0813	. 2467	. 3940
164,000 TO 207,000 POUNDS G.V.W.						
Tire cost				$0. 0974	$0. 2953	$0. 4712
Operating cost			$0. 2527			
Dependent cost		$0. 0590	. 0590			
Fixed cost	$0. 0608	. 0608	. 0608			
Total	. 0608	. 1198	. 3725	. 0974	. 2953	. 4712

[1] *J*=Cost for period when truck is shut down due to seasonal layoff, overhaul, or other such causes.
N=Cost for period when truck is in operating status but not actually hauling logs.
C=Cost for period when truck is actually hauling logs—less tires.
D=Tire cost.

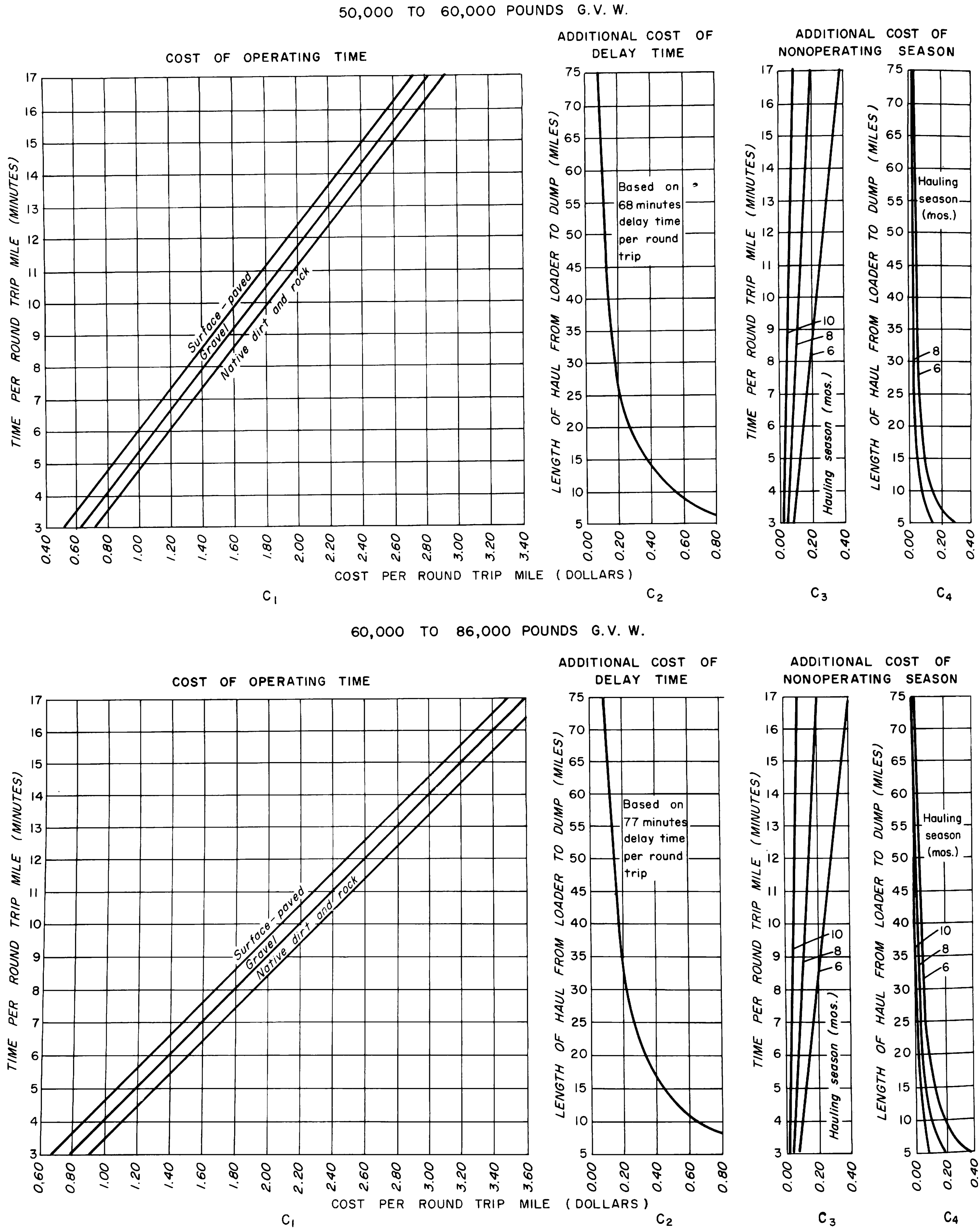


FIGURE 18.—Cost of log hauling per round trip mile for 50,000- to 60,000-lb. and 60,000- to 86,000-lb. g.v.w. loads, Western United States, 1957.

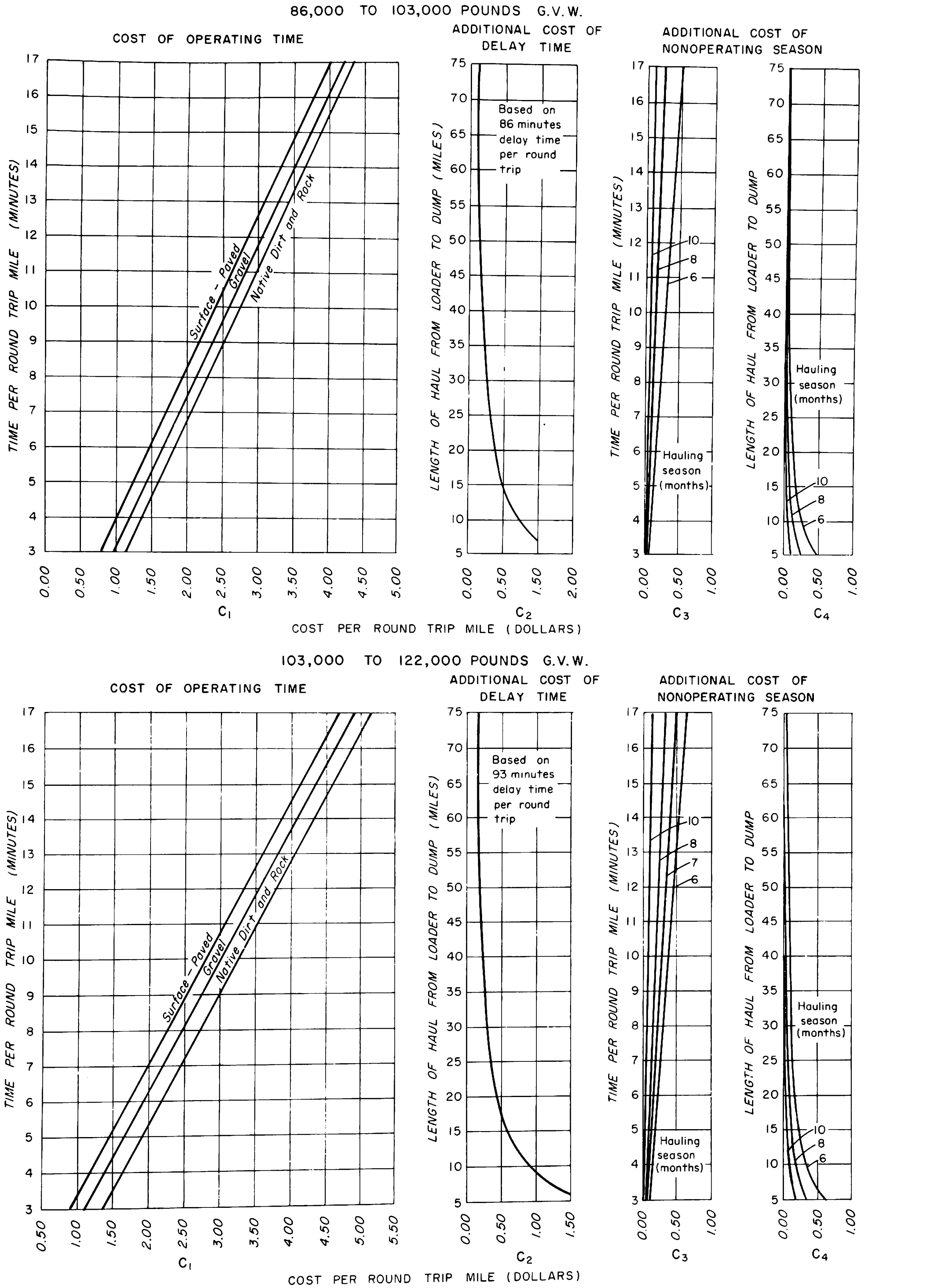


FIGURE 19.—Cost of log hauling per round trip mile for 86,000- to 103,000-lb. and 103,000- to 122,000-lb. g. v. w. loads, Western United States, 1957.

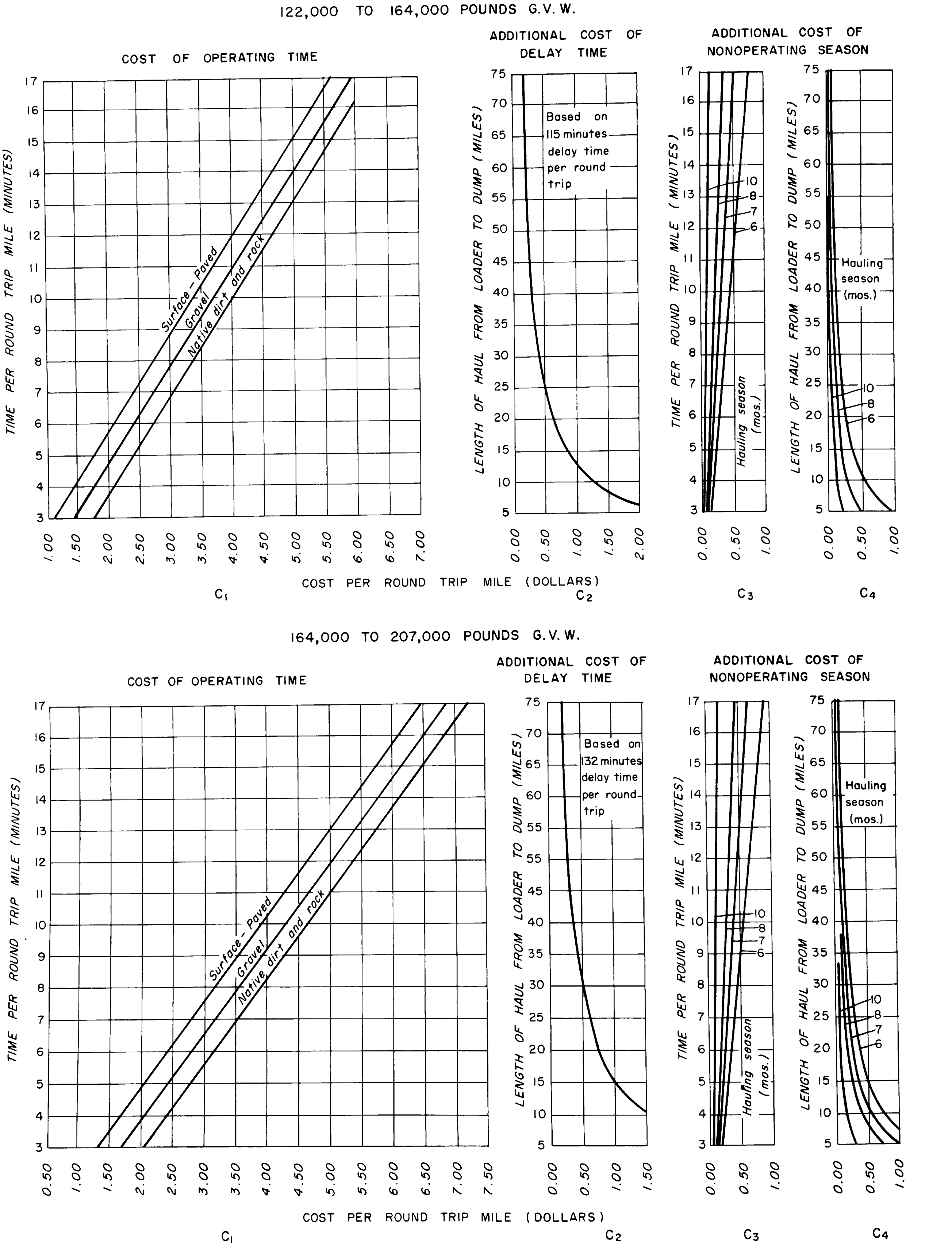


FIGURE 20.—Cost of log hauling per round trip mile for 122,000- to 164,000-lb. and 164,000- to 207,000-lb. g.v.w. loads, Western United States, 1957.

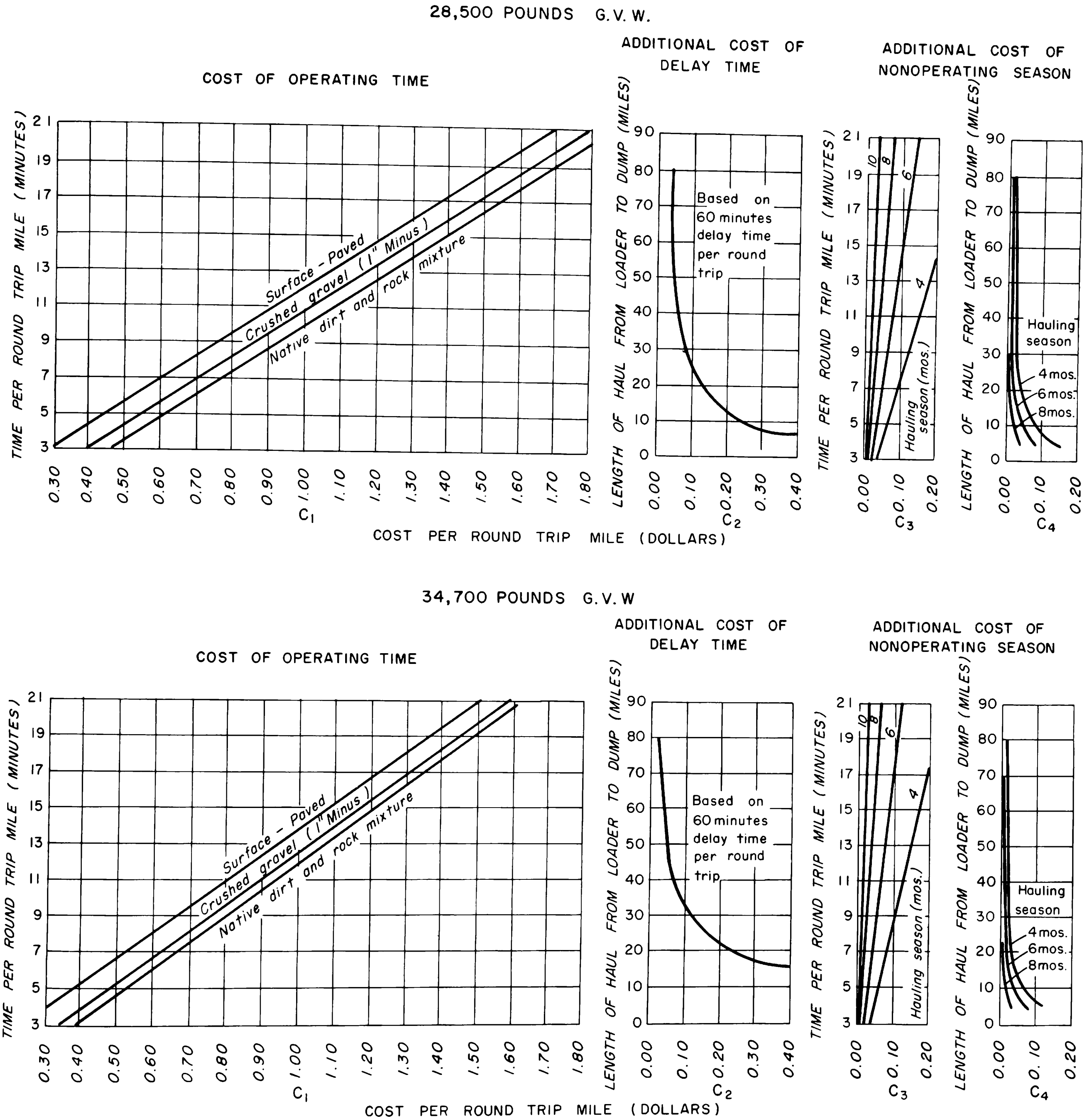


FIGURE 21.—Cost of log hauling per round trip mile for 28,500- and 34,700-lb. g.v.w. loads (avg. loads 1.84 and 2.27 M bd. ft., respectively), Eastern United States, 1952.

TABLE 9.—*Hauling cost, by periods,[1] for gasoline trucks, Eastern United States, 1952*

Item	Cost per minute			Cost per mile *D*		
	J	*N*	*C*	Pavement	Gravel	Dirt
28,400 POUNDS G.V.W.						
Tire cost				$0. 0281	$0. 0704	$0. 0931
Operating cost			$0. 0319			
Dependent cost		$0. 0314	. 0314			
Fixed cost	$0. 0058	. 0058	. 0058			
Total	. 0058	. 0372	. 0691	. 0281	. 0704	. 0931
34,700 POUNDS G.V.W.						
Tire cost				$0. 0337	$0. 0845	$0. 1120
Operating cost			$0. 0392			
Dependent cost		$0. 0314	. 0314			
Fixed cost	$0. 0069	. 0069	. 0069			
Total	. 0069	. 0383	. 0775	. 0337	. 0845	. 11[illegible]

[1] *J*=Cost for period when truck is shut down due to seasonal layoff, overhaul, or other cause.
N=Cost for period when truck is in operating status but not actually hauling logs.
C=Cost for period when truck is actually hauling logs, less tires.
D=Tire cost.

U.S. DEPARTMENT OF AGRICULTURE
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Logging Road Handbook: The Effect of Road Design on Hauling Costs
Agriculture Handbook No. 183. December 1960.

ADDENDA -- December 1962

Page 32:

Table 10.--Travel time for round trip mile for "on highway" trucks

Class of road	Percent of grade in direction of load						
	+3	+2	+1	0	-1	-2	-3
1. Highway (curves superelevated):	Mins.	Mins.	Mins.	Mins.	Mins.	Mins.	Mins.
A. Alinement excellent:							
1. Paved	5.10	4.07	3.40	2.88	2.53	2.83	3.15

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Table 12.--Approximate log hauling costs per M bd. ft. per round trip mile for "on highway" trucks, Western United States, 1957

Class of road	Percent of grade in direction of load						
	+3	+2	+1	0	-1	-2	-3
1. Highway (curves superelevated):	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
A. Alinement excellent:							
1. Paved	0.213	0.172	0.146	0.124	0.113	0.124	0.137

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APPROXIMATION METHODS

Time of Travel

Occasionally it is necessary to estimate the cost f hauling logs before a road is designed. There- ore, tables 10 and 11 were compiled for approxi- iating time of travel over various classes of roads. 'rom these tables, the mileage for each class of oad can be determined and added up, and the total ength of haul and average time per mile calcu- ated. With this data, the cost per mile of haul nd the total cost can be determined from figures 8 to 21, inclusive, pp. 26 to 29.

Hauling Cost

A simple method of determining approximate hauling costs, but less accurate than the one for time of travel, is given in tables 12 to 14, inclusive. In order to present the data in such a simple form, it was necessary to assume certain fixed conditions: (1) an 8-month hauling season for all classes of roads, and (2) a weight of 8 pounds per board foot for logs in Western United States and 10 pounds in Eastern. Examples of the computation of approximate costs are given at the bottom of the tables.

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TABLE 10.—*Travel time for round trip mile for "on highway" trucks*

(B=1.9 loaded.[1] B=5.3 empty.)

Class of road [2]	Percent of grade in direction of load																							
	+10	+9	+8	+7	+6	+5	+4	+3	+2	+1	0	−1	−2	−3	−4	−5	−6	−7	−8	−9	−10	−11	−12	−13	−14
1. Highway (curves superelevated):																									
A. Alinement excellent:	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*
1. Paved	12.70	11.65	10.55	9.50	8.45	7.35	6.25	5.10	4.01	3.40	2.88	2.53	2.83	3.15	3.65	4.15	4.63	5.15	5.65	6.20	6.75	7.25	7.80	8.40	8.95
2. Double lane (not superelevated):																									
A. Alinement excellent:																									
1. Paved	12.70	11.65	10.55	9.50	8.45	7.35	6.25	5.25	4.40	3.70	3.18	3.18	3.18	3.33	3.65	4.15	4.63	5.15	5.65	6.20	6.75	7.25	7.80	8.40	8.95
2. Gravel	13.15	12.10	11.00	9.95	8.85	7.75	6.70	5.60	4.80	4.10	3.45	3.18	3.23	3.43	3.75	4.25	4.75	5.30	5.85	6.35	6.95	7.40	7.95	8.55	9.10
B. Alinement good:																									
1. Paved	12.70	11.65	10.55	9.50	8.45	7.35	6.25	5.30	4.65	3.95	3.60	3.60	3.60	3.60	3.75	4.15	4.63	5.15	5.65	6.20	6.75	7.25	7.80	8.40	8.95
2. Gravel	13.15	12.10	11.00	9.95	8.85	7.75	6.70	5.85	5.05	4.35	3.70	3.60	3.60	3.60	3.85	4.25	4.75	5.30	5.85	6.35	6.95	7.40	7.95	8.55	9.10
C. Alinement fair:																									
1. Paved	12.70	11.65	10.55	9.50	8.45	7.43	6.58	5.83	4.98	4.28	4.23	4.23	4.23	4.23	4.23	4.30	4.63	5.15	5.65	6.20	6.75	7.25	7.80	8.40	8.95
2. Gravel	13.15	12.10	11.00	9.95	8.85	7.83	7.03	6.18	5.38	4.68	4.23	4.23	4.23	4.23	4.23	4.40	4.75	5.30	5.85	6.35	6.95	7.40	7.95	8.55	9.10
3. Lane and one-half with turnouts (car lane and truck lane with 4-ft. ditch): [3]																									
A. Alinement excellent:																									
1. Paved	12.70	11.65	10.55	9.50	8.45	7.35	6.32	5.57	4.72	4.02	3.87	3.87	3.87	3.87	3.95	4.20	4.63	5.15	5.65	6.20	6.75	7.25	7.80	8.40	8.95
2. Gravel	13.15	12.10	11.00	9.95	8.85	7.75	6.77	5.92	5.12	4.42	3.87	3.87	3.87	3.87	4.05	4.25	4.75	5.30	5.85	6.35	6.95	7.40	7.95	8.55	9.10
B. Alinement good:																									
1. Paved	12.70	11.65	10.55	9.50	8.51	7.66	6.81	6.06	5.21	4.82	4.82	4.82	4.82	4.82	4.82	4.82	4.88	5.16	5.65	6.20	6.75	7.25	7.80	8.40	8.95
2. Gravel	13.15	12.10	11.00	9.95	8.91	8.06	7.26	6.41	5.61	4.91	4.82	4.82	4.82	4.82	4.82	4.82	5.01	5.31	5.85	6.35	6.95	7.40	7.95	8.55	9.10
C. Alinement fair:																									
1. Paved	12.70	11.65	10.60	9.80	9.00	8.15	7.30	6.55	5.78	5.78	5.78	5.78	5.78	5.78	5.78	5.78	5.78	5.78	5.88	6.20	6.75	7.25	7.80	8.40	8.95
2. Gravel	13.15	12.10	11.05	10.25	9.40	8.55	7.75	6.90	6.10	5.78	5.78	5.78	5.78	5.78	5.78	5.78	5.78	5.78	6.08	6.35	6.95	7.40	7.95	8.55	9.10
4. Single lane with turnouts (truck lane with 3-ft. ditch): [3]																									
A. Alinement excellent:																									
1. Paved	12.70	11.65	10.55	9.50	8.45	7.35	6.43	5.68	4.83	4.13	4.13	4.13	4.13	4.13	4.13	4.35	4.63	5.15	5.65	6.20	6.75	7.25	7.80	8.40	8.95
2. Gravel	13.15	12.10	11.00	9.95	8.85	7.75	6.88	6.03	5.23	4.53	4.13	4.13	4.13	4.13	4.20	4.45	4.75	5.30	5.85	6.35	6.95	7.40	7.95	8.55	9.10
B. Alinement good:																									
1. Paved	12.70	11.65	10.55	9.50	8.62	7.77	6.92	6.17	5.32	5.12	5.12	5.12	5.12	5.12	5.12	5.12	5.12	5.35	5.65	6.20	6.75	7.25	7.80	8.40	8.95
2. Gravel	13.15	12.10	11.00	9.95	9.02	8.17	7.37	6.52	5.72	5.12	5.12	5.12	5.12	5.12	5.12	5.12	5.20	5.50	5.85	6.35	6.95	7.40	7.95	8.55	9.10
3. Dirt	13.60	12.50	11.40	10.30	9.37	8.57	7.72	6.87	6.07	5.27	5.12	5.12	5.12	5.12	5.12	5.12	5.30	5.60	5.95	6.50	7.05	7.55	8.10	8.70	9.20
C. Alinement fair:																									
1. Paved	12.70	11.65	10.80	10.00	9.20	8.35	7.50	6.75	6.23	6.23	6.23	6.23	6.23	6.23	6.23	6.23	6.23	6.23	6.23	6.43	6.75	7.25	7.80	8.40	8.95
2. Gravel	13.15	12.10	11.25	10.45	9.60	8.75	7.95	7.10	6.30	6.23	6.23	6.23	6.23	6.23	6.23	6.23	6.23	6.23	6.33	6.58	6.95	7.40	7.95	8.55	9.10
3. Dirt	13.60	12.50	11.65	10.80	9.95	9.15	8.30	7.45	6.65	6.23	6.23	6.23	6.23	6.23	6.23	6.23	6.23	6.23	6.43	6.73	7.05	7.55	8.10	8.70	9.20
D. Alinement poor:																									
2. Gravel	13.53	12.73	11.88	11.08	10.23	9.38	8.58	7.73	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.52	7.82	8.12	8.55	9.10
3. Dirt	13.98	13.13	12.28	11.43	10.58	9.78	8.93	8.08	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.67	7.97	8.27	8.70	9.20
5. Single lane with turnouts (truck lane without ditch): [3]																									
B. Alinement good:																									
3. Dirt	13.60	12.50	11.40	10.32	9.47	8.67	7.82	6.97	6.17	5.37	5.25	5.25	5.25	5.25	5.25	5.25	5.33	5.63	5.95	6.50	7.05	7.55	8.10	8.70	9.20
C. Alinement fair:																									
3. Dirt	13.60	12.69	11.84	10.99	10.14	9.34	8.49	7.64	6.84	6.54	6.54	6.54	6.54	6.54	6.54	6.54	6.54	6.54	6.55	6.85	7.15	7.55	8.10	8.70	9.20
D. Alinement poor:																									
3. Dirt	14.45	13.60	12.75	11.90	11.05	10.25	9.40	8.46	8.46	8.46	8.46	8.46	8.46	8.46	8.46	8.46	8.46	8.46	8.46	8.46	8.46	8.46	8.76	9.06	9.31

[1] $B = \frac{hp. \times 70\%}{g.v.w. \text{ (in 1,000 lbs.)}}$

[2] Alinement classification basis:

Poor $= \frac{\textit{Average radius}}{\textit{No. of curves per mile}}$ = less than 20

Fair = do. = 20 to 50
Good = do. = 50 to 100
Excellent = do. = over 100

[3] On single-lane or lane-and-one-half roads, increase the time for passing vehicles on turnouts by the percent shown in following tabulation. Consider all vehicles for single-lane roads and only trucks for lane-and-one-half roads.

Turnout spacing (feet)	Increased time when number of vehicles passing over road per hour is—			
	5	10	15	20
	Percent	*Percent*	*Percent*	*Percent*
250	2.0	4.0	6.0	8.0
500	2.6	5.4	8.0	10.7
750	3.4	6.8	10.2	13.6

TABLE 11.—*Travel time per round trip mile, for "off highway" trucks*

(B=1.6 loaded.[1] B=4.2 empty.)

Class of road [2]	Percent of grade in direction of load																							
	+10	+9	+8	+7	+6	+5	+4	+3	+2	+1	0	−1	−2	−3	−4	−5	−6	−7	−8	−9	−10	−11	−12	−13	−14
1. Double lane (not superelevated):																									
A. Alinement excellent:	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*	*Mins.*
1. Paved	14.65	13.40	12.15	10.90	9.67	8.42	7.19	5.94	4.95	4.10	3.36	3.20	3.40	3.66	4.04	4.56	5.15	5.77	6.39	7.11	7.66	8.28	8.93	9.53	10.17
2. Gravel	15.23	13.93	12.65	11.39	10.13	8.85	7.59	6.31	5.30	4.50	3.69	3.29	3.52	3.82	4.19	4.73	5.35	5.96	6.57	7.29	7.84	8.45	9.08	9.71	10.43
B. Alinement good:																									
1. Paved	14.65	13.40	12.15	10.90	9.67	8.42	7.19	6.19	5.20	4.35	3.61	3.60	3.60	3.81	4.13	4.56	5.15	5.77	6.39	7.11	7.66	8.28	8.93	9.53	10.17
2. Gravel	15.23	13.93	12.65	11.39	10.13	8.85	7.59	6.56	5.55	4.75	3.94	3.60	3.67	3.97	4.28	4.73	5.35	5.96	6.57	7.29	7.84	8.45	9.08	9.71	10.43
C. Alinement fair:																									
1. Paved	14.65	13.40	12.15	10.90	9.67	8.50	7.52	6.52	5.53	4.68	4.23	4.23	4.23	4.23	4.43	4.71	5.15	5.77	6.39	7.11	7.66	8.28	8.93	9.53	10.17
2. Gravel	15.23	13.93	12.65	11.39	10.13	8.93	7.92	6.89	5.88	5.08	4.27	4.23	4.23	4.27	4.58	4.88	5.35	5.96	6.57	7.29	7.84	8.45	9.08	9.71	10.43
2. Lane and one-half with turnouts (car lane and truck lane with 4-ft. ditch): [3]																									
A. Alinement excellent:																									
1. Paved	14.65	13.40	12.15	10.90	9.67	8.42	7.26	6.26	5.27	4.42	3.87	3.87	3.87	4.01	4.33	4.61	5.15	5.77	6.39	7.11	7.66	8.28	8.93	9.53	10.17
2. Gravel	15.23	13.93	12.65	11.39	10.13	8.85	7.66	6.63	5.62	4.82	4.01	3.87	3.87	4.17	4.48	4.78	5.35	5.96	6.57	7.29	7.84	8.45	9.08	9.71	10.43
B. Alinement good:																									
1. Paved	14.65	13.40	12.15	10.90	9.73	8.73	7.75	6.75	5.76	4.91	4.82	4.82	4.82	4.82	4.82	5.07	5.41	5.78	6.39	7.11	7.66	8.28	8.93	9.53	10.17
2. Gravel	15.23	13.93	12.65	11.39	10.19	9.16	8.15	7.12	6.11	5.31	4.82	4.82	4.82	4.82	4.94	5.24	5.61	5.97	6.57	7.29	7.84	8.45	9.08	9.71	10.43
C. Alinement fair:																									
1. Paved	14.65	13.40	12.20	11.20	10.22	9.22	8.24	7.24	6.25	5.78	5.78	5.78	5.78	5.78	5.78	5.78	5.88	6.25	6.62	7.11	7.66	8.28	8.93	9.53	10.17
2. Gravel	15.23	13.93	12.70	11.69	10.68	9.65	8.64	7.61	6.60	5.80	5.78	5.78	5.78	5.78	5.78	5.78	6.08	6.44	6.80	7.29	7.84	8.45	9.08	9.71	10.43
3. Single lane with turnouts (truck lane with 3-ft. ditch): [3]																									
A. Alinement excellent:																									
1. Paved	14.65	13.40	12.15	10.90	9.67	8.42	7.37	6.37	5.38	4.53	4.13	4.13	4.13	4.16	4.48	4.76	5.15	5.77	6.39	7.11	7.66	8.28	8.93	9.53	10.17
2. Gravel	15.23	13.93	12.65	11.39	10.13	8.85	7.77	6.74	5.73	4.93	4.13	4.13	4.13	4.32	4.63	4.93	5.35	5.96	6.57	7.29	7.84	8.45	9.08	9.71	10.43
B. Alinement good:																									
1. Paved	14.65	13.40	12.15	10.90	9.84	8.84	7.86	6.86	5.87	5.12	5.12	5.12	5.12	5.12	5.12	5.26	5.60	5.97	6.39	7.11	7.66	8.28	8.93	9.53	10.17
2. Gravel	15.23	13.93	12.65	11.39	10.30	9.27	8.26	7.23	6.22	5.42	5.12	5.12	5.12	5.12	5.13	5.43	5.80	6.16	6.57	7.29	7.84	8.45	9.08	9.71	10.43
3. Dirt	15.55	14.30	13.05	11.80	10.72	9.72	8.72	7.72	6.72	5.77	5.12	5.12	5.12	5.12	5.25	5.53	6.02	6.29	6.72	7.44	7.97	8.62	9.25	9.88	10.51
C. Alinement fair:																									
1. Paved	14.65	13.40	12.40	11.40	10.42	9.42	8.44	7.44	6.45	6.23	6.23	6.23	6.23	6.23	6.23	6.23	6.23	6.50	6.87	7.25	7.66	8.28	8.93	9.53	10.17
2. Gravel	15.23	13.93	12.90	11.89	10.88	9.85	8.84	7.81	6.80	6.23	6.23	6.23	6.23	6.23	6.23	6.23	6.33	6.69	7.05	7.43	7.84	8.45	9.08	9.71	10.43
3. Dirt	15.55	14.30	13.30	12.30	11.30	10.30	9.30	8.30	7.30	6.35	6.23	6.23	6.23	6.23	6.23	6.23	6.55	6.82	7.20	7.58	7.97	8.62	9.25	9.88	10.51
D. Alinement poor:																									
2. Gravel	15.61	14.56	13.53	12.52	11.51	10.48	9.47	8.44	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.69	8.07	8.46	8.82	9.20	9.71	10.43
3. Dirt	15.93	14.93	13.93	12.93	11.93	10.93	9.93	8.93	7.93	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.84	8.22	8.59	8.99	9.37	9.88	10.51
4. Single lane with turnouts (truck lane without ditch): [3]																									
B. Alinement good:																									
3. Dirt	15.55	14.30	13.05	11.82	10.82	9.82	8.82	7.82	6.82	5.87	5.25	5.25	5.25	5.25	5.28	5.56	6.05	6.32	6.72	7.44	7.97	8.62	9.25	9.88	10.51
C. Alinement fair:																									
3. Dirt	15.55	14.49	13.49	12.49	11.49	10.49	9.49	8.49	7.49	6.54	6.54	6.54	6.54	6.54	6.54	6.54	6.67	6.94	7.32	7.70	8.07	8.62	9.25	9.88	10.51
D. Alinement poor:																									
3. Dirt	16.40	15.40	14.40	13.40	12.40	11.40	10.40	9.40	8.46	8.46	8.46	8.46	8.46	8.46	8.46	8.46	8.46	8.46	8.46	8.71	9.08	9.48	9.86	10.24	10.62

[1] $B = \frac{hp. \times 70\%}{g.v.w.\text{ (in 1,000 lbs.)}}$

[2] Alinement classification basis:

Poor $= \frac{\textit{Average radius}}{\textit{No. of curves per mile}}$ = less than 20
Fair = do. = 20 to 50
Good = do. = 50 to 100
Excellent = do. = over 100

[3] On single-lane or lane-and-one-half roads, increase the time for passing vehicles on turnouts by the percent shown in following tabulation. Consider all vehicles for single-lane roads and only trucks for lane-and-one-half roads.

Turnout spacing (feet)	Increased time when number of vehicles passing over road per hour is—			
	5	10	15	20
	Percent	*Percent*	*Percent*	*Percent*
250	2.0	4.0	6.0	8.0
500	2.6	5.4	8.0	10.7
750	3.4	6.8	10.2	13.6

TABLE 12.—*Approximate log hauling costs per M bd. ft. per round trip mile for "on highway" trucks, Western United States, 1957* [1]

(B=1.9 loaded. B=5.3 empty.)

Class of road	Percent of grade in direction of load																								
	+10	+9	+8	+7	+6	+5	+4	+3	+2	+1	0	−1	−2	−3	−4	−5	−6	−7	−8	−9	−10	−11	−12	−13	−14
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
1. Highway (curves superelevated):																									
A. Alinement excellent:																									
1. Paved	0.512	0.469	0.428	0.386	0.344	0.302	0.261	0.213	0.172	0.146	0.124	0.113	0.124	0.137	0.154	0.174	0.194	0.215	0.236	0.257	0.279	0.300	0.322	0.344	0.365
2. Double lane:																									
A. Alinement excellent: [2]																									
1. Paved	.512	.469	.428	.386	.344.	.302	.261	0.220	0.187	0.158	0.139	0.139	0.139	0.144	.156	.174	.194	.215	.236	.257	.279	.300	.322	.344	.365
2. Gravel	.555	.513.	.469	.426	.382	.339	.296	.255	.221	.193	.171	.157	.158	.167	.182	.201	.222	.243	.264	.286	.307	.328	.350	.371	.393
B. Alinement good:																									
1. Paved	.512	.469	.428	.386	.344	.302	.261	.223	.191	.167	.154	.154	.154	.154	.159	.174	.194	.215	.236	.257	.279	.300	.322	.344	.365
2. Gravel	.555	.513	.469	.426	.382	.339	.296	.264	.233	.206	.183	.176	.176	.176	.185	.201	.222	.243	.264	.286	.307	.328	.350	.371	.393
C. Alinement fair:																									
1. Paved	.512	.469	.428	.386	.344	.305	.273	.243	.210	.182	.180	.180	.180	.180	.180	.182	.194	.215.	.236	.257	.279	.300	.322	.344	.365
2. Gravel	.555	.513	.469	.426	.382	.339	.308	.277	.249	.223	.202	.202	.202	.202	.202	.209	.222	.243	.264	.286	.307	.328	.350	.371	.393
3. Lane and one-half with turnouts (car lane and truck lane with 4-ft. ditch): [3]																									
A. Alinement excellent:																									
1. Paved	.512	.469	.428	.386	.344	.302	.261	.231	.200	.173	.165	.165	.165	.165	.168	.178	.194	.215	.236	.257	.279	.300	.322	.344	.365
2. Gravel	.555	.513.	.469	.426	.382	.339	.300	.269	.237	.211	.188	.185	.185	.185	.192	.201	.222	.243	.264	.286	.307	.328	.350	.371	.393
B. Alinement good:																									
1. Paved	.512	.469	.428	.386	.347	.317	.285	.253	.221	.200	.200	.200	.200	.200	.200	.200	.205	.217	.236	.257	.279	.300	.322	.344	.365
2. Gravel	.555	.513	.469	.426	.386	.351	.316	.284	.254	.228	.224	.224	.224	.224	.224	.224	.232	.243	.264	.286	.307	.328	.350	.371	.393
C. Alinement fair:																									
1. Paved	.512	.469	.433	.400	.367	.333	.300	.267	.241	.241	.241	.241	.241	.241	.241	.241	.241	.241	.245	.257	.279	.300	.322	.344	.365
2. Gravel	.555	.513	.469	.437	.404	.370	.337	.305	.271	.261	.261	.261	.261	.261	.261	.261	.261	.261	.272	.286	.307	.328	.350	.371	.393
4. Single lane with turnouts (truck lane with 3-ft. ditch):																									
A. Alinement excellent:																									
1. Paved	.512	.469	.428	.386	.344	.302	.267	.237	.204	.176	.176	.176	.176	.176	.176	.180	.194	.215	.236	.257	.279	.300	.322	.344	.365
2. Gravel	.555	.513	.469	.426	.382	.339	.305	.274	.246	.219	.198	.198	.198	.198	.198	.207	.222	.243	.264	.286	.307	.328	.350	.371	.393
B. Alinement good:																									
1. Paved	.512	.469	.428	.386	.352	.320	.290	.260	.231	.215	.215	.215	.215	.215	.215	.215	.215	.223	.236	.257	.279	.300	.322	.344	.365
2. Gravel	.555	.513	.469	.426	.389	.356	.324	.293	.263	.237	.237	.237	.237	.237	.237	.237	.239	.252	.264	.286	.307	.328	.350	.271	.393
3. Dirt	.593	.550	.507	.463	.426	.395	.361	.328	.295	.263	.257	.257	.257	.257	.257	.257	.265	.276	.291	.313	.334	.355	.376	.398	.419
C. Alinement fair:																									
1. Paved	.512	.469	.438	.406	.374	.343	.311	.280	.258	.258	.258	.258	.258	.258	.258	.258	.258	.258	.258	.267	.279	.300	.322	.344	.365
2. Gravel	.555	.513	.478	.446	.413	.380	.346	.313	.281	.280	.280	.280	.280	.280	.280	.280	.280	.280	.283	.293	.307	.328	.350	.371	.393
3. Dirt	.593	.550	.512	.480	.448	.416	.384	.351	.319	.302	.302	.302	.302	.302	.302	.302	.302	.302	.309	.324	.334	.355	.376	.398	.419
D. Alinement poor:																									
2. Gravel	.571	.537	.503	.470	.437	.403	.371	.339	.328	.328	.328	.328	.328	.328	.328	.328	.328	.328	.328	.328	.330	.342	.355	.371	.393
3. Dirt	.608	.574	.541	.508	.474	.441	.408	.374	.350	.350	.350	.350	.350	.350	.350	.350	.350	.350	.350	.350	.358	.370	.384	.398	.419
5. Single lane with turnouts (truck lane without ditch):																									
A. Alinement good, dirt	.593	.550	.507	.463	.430	.398	.365	.332	.298	.267	.263	.263	.263	.263	.263	.263	.269	.278	.291	.313	.334	.355	.376	.398	.419
B. Alinement fair, dirt	.593	.558	.524	.491	.458	.424	.391	.357	.326	.315	.315	.315	.315	.315	.315	.315	.315	.315	.315	.325	.339	.355	.376	.398	.419
C. Alinement poor, dirt	.628	.593	.560	.526	.492	.457	.423	.389	.389	.389	.380	.389	.389	.389	.389	.389	.389	.389	.389	.389	.389	.389	.400	.413	.425

[1] Based on 8-month hauling season; 8 pounds per board foot (for timber of other weights, multiply the cost per M bd. ft. per mile by actual weight per bd. ft. divided by 8); 4.5 to 6 M bd. ft. per load—8-foot bunks; delay or standby cost per M bd. ft., $1.32. Federal fuel tax of 3 cents included in costs shown; State fuel taxes and fees are excluded.

[2] Alinement factor (curves not superelevated):

$$\text{Excellent} = \frac{\textit{Average radius}}{\textit{No. of curves per mile}} = \text{over } 100$$

Good	=	do.	= 50 to 100
Fair	=	do.	= 20 to 50
Poor	=	do.	= less than 20

[3] On single-lane or lane-and-one-half roads, increase the cost for time lost in passing vehicles on turnouts by the percent shown in following tabulation. Consider all vehicles for single-lane roads and only trucks for lane-and-one-half roads.

Turnout spacing (feet)	Increased cost when number of vehicles passing over road per hour is—			
	5	10	15	20
	Percent	*Percent*	*Percent*	*Percent*
250	2.0	4.0	6.0	8.0
500	2.6	5.4	8.0	10.7
750	3.4	6.8	10.2	13.6

Example. Consider a 24-mile log haul using "on-highway" trucks over the following road conditions:

Section	Length	Standard of road	Alinement	Surface	Grade in direction of load
	Miles				*Percent*
1	14	Double lane	Excellent	Paved	−0.5
2	4	do	do	do	+3.0
3	4	Single lane with ditch	Fair	Gravel	−7.0
4	2	Single lane without ditch	Poor	Dirt	+5.0

Cost of delay time per M bd. ft. = $1.32.

To determine hauling cost per M bd. ft.:

Section	Length	Cost per M bd. ft. per mile	Cost per section
	Miles	*Dollars*	*Dollars*
1	14	0.139	1.946
2	4	.220	.880
3	4	.280	1.120
4	2	.457	.914
Total	24	1.096	4.860
Cost of delay time			1.320
Total hauling cost per M bd. ft.			6.180

Type of haul	*Cost index* 1959	1960	1961
Legal size "on highway," 4.5-6 M bd. ft	1.12		
Legal size "off highway," 4.5-6 M bd. ft	1.05		

TABLE 13.—*Approximate log hauling costs per M bd. ft. per round trip mile for "off-highway" trucks, Western United States, 1957* [1]

(B=1.6 loaded. B=4.2 empty.)

Class of road [2]	Percent of grade in direction of load																								
	+10	+9	+8	+7	+6	+5	+4	+3	+2	+1	0	−1	−2	−3	−4	−5	−6	−7	−8	−9	−10	−11	−12	−13	−14
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
2. Double lane:																									
A. Alinement excellent:																									
1. Paved	0.489	0.447	0.407	0.366	0.326	0.285	0.244	0.203	0.168	0.141	0.120	0.115	0.119	0.129	0.142	0.159	0.179	0.199	0.220	0.240	0.260	0.280	0.300	0.320	0.341
2. Gravel	.530	.487	.445	.405	.364	.323	.282	.240	.207	.177	.155	.144	.148	.157	.170	.187	.208	.228	.249	.270	.290	.310	.331	.352	.373
B. Alinement good:																									
1. Paved	.489	.447	.407	.366	.326	.285	.244	.207	.177	.150	.129	.125	.125	.134	.145	.159	.179	.199	.220	.240	.260	.280	.300	.320	.341
2. Gravel	.530	.487	.445	.405	.364	.323	.282	.245	.213	.186	.162	.150	.153	.162	.173	.187	.208	.228	.249	.270	.290	.310	.331	.352	.373
C. Alinement fair:																									
1. Paved	.489	.447	.407	.366	.326	.287	.251	.218	.191	.166	.148	.148	.148	.148	.156	.166	.179	.199	.220	.240	.260	.280	.300	.320	.341
2. Gravel	.530	.487	.445	.405	.364	.326	.291	.258	.226	.199	.174	.173	.173	.174	.183	.194	.208	.228	.249	.270	.290	.310	.331	.352	.373
3. Lane and one-half with turnouts (car lane and truck lane with 4-foot ditch): [3]																									
A. Alinement excellent:																									
1. Paved	.489	.447	.407	.366	.326	.285	.249	.213	.182	.156	.135	.135	.135	.140	.148	.159	.179	.199	.220	.240	.260	.280	.300	.320	.341
2. Gravel	.530	.487	.445	.405	.364	.323	.284	.250	.218	.190	.165	.160	.160	.167	.177	.191	.208	.228	.249	.270	.290	.310	.331	.352	.373
B. Alinement good:																									
1. Paved	.489	.447	.407	.366	.330	.293	.259	.227	.198	.170	.166	.166	.166	.166	.166	.174	.186	.199	.220	.240	.260	.280	.300	.320	.341
2. Gravel	.530	.487	.445	.405	.366	.333	.300	.267	.233	.207	.191	.191	.191	.191	.195	.204	.216	.228	.249	.270	.290	.310	.331	.352	.373
C. Alinement fair:																									
1. Paved	.489	.447	.407	.375	.343	.311	.278	.247	.215	.198	.198	.198	.198	.198	.198	.198	.200	.212	.227	.240	.260	.280	.300	.320	.341
2. Gravel	.530	.487	.448	.415	.382	.349	.316	.284	.250	.224	.223	.223	.223	.223	.223	.223	.233	.246	.258	.270	.290	.310	.331	.352	.373
4. Single lane with turnouts (truck lane with 3-foot ditch): [3]																									
A. Alinement excellent:																									
1. Paved	.489	.447	.407	.366	.326	.285	.249	.216	.187	.162	.145	.145	.145	.145	.154	.165	.179	.199	.220	.240	.260	.280	.300	.320	.341
2. Gravel	.530	.487	.445	.405	.364	.323	.286	.253	.222	.194	.168	.168	.168	.173	.181	.193	.208	.228	.249	.270	.290	.310	.331	.352	.373
B. Alinement good:																									
1. Paved	.489	.447	.407	.366	.332	.298	.264	.234	.203	.176	.176	.176	.176	.176	.176	.181	.191	.204	.220	.240	.260	.280	.300	.320	.341
2. Gravel	.530	.487	.445	.405	.370	.337	.304	.271	.238	.212	.201	.201	.201	.201	.201	.211	.223	.236	.249	.270	.290	.310	.331	.352	.373
3. Dirt	.569	.528	.487	.448	.410	.379	.346	.314	.282	.248	.229	.229	.229	.229	.230	.241	.253	.265	.280	.301	.321	.341	.362	.383	.403
C. Alinement fair:																									
1. Paved	.489	.447	.414	.382	.350	.317	.285	.251	.221	.213	.213	.213	.213	.213	.213	.213	.213	.223	.234	.246	.260	.280	.300	.320	.341
2. Gravel	.530	.487	.455	.422	.389	.355	.323	.289	.255	.238	.238	.238	.238	.238	.238	.238	.239	.251	.264	.276	.290	.310	.331	.352	.373
3. Dirt	.569	.528	.496	.462	.430	.398	.364	.333	.299	.270	.265	.265	.265	.265	.265	.265	.275	.284	.297	.309	.321	.341	.362	.382	.403
D. Alinement poor:																									
2. Gravel	.543	.510	.477	.443	.410	.376	.343	.310	.280	.280	.280	.280	.280	.280	.280	.280	.280	.280	.286	.298	.310	.323	.337	.352	.373
3. Dirt	.580	.548	.515	.483	.451	.418	.386	.353	.321	.307	.307	.307	.307	.307	.307	.307	.307	.307	.316	.329	.341	.355	.367	.382	.403
5. Single lane with turnouts (truck lane without ditch): [3]																									
B. Alinement good, dirt	.569	.528	.487	.448	.415	.383	.350	.316	.284	.252	.232	.232	.232	.232	.234	.243	.253	.265	.280	.301	.321	.341	.362	.382	.403
C. Alinement fair, dirt	.569	.534	.501	.469	.436	.404	.372	.339	.307	.275	.275	.275	.275	.275	.275	.275	.280	.287	.300	.312	.325	.341	.362	.382	.403
D. Alinement poor, dirt	.595	.563	.532	.499	.467	.435	.403	.370	.338	.338	.338	.338	.338	.338	.338	.338	.338	.338	.338	.345	.358	.371	.383	.396	.408

[1] Based on 8-month hauling season; 8 pounds per board foot (for timber of other weights, multiply the cost per M bd. ft. per mile by actual weight per bd. ft. divided by 8); 7.5 to 10 M bd. ft. per load; delay or standby cost per M bd. ft., $1.19. Federal fuel tax of 3 cents included in costs shown.

[2] Alinement factor (curves not superelevated):

$$\text{Excellent} = \frac{\textit{Average radius}}{\textit{No. of curves per mile}} = \text{over } 100$$

Good	=	do.	=50 to 100
Fair	=	do.	=20 to 50
Poor	=	do.	=less than 20

[3] On single-lane or lane-and-one-half roads, increase the cost for time lost in passing vehicles on turnouts by the percent shown in following tabulation. Consider all vehicles for single-lane roads and only trucks for lane-and-one-half roads.

Turnout spacing (feet)	Increased cost when number of vehicles passing over road per hour is—			
	5	10	15	20
	Percent	*Percent*	*Percent*	*Percent*
250	2.0	4.0	6.0	8.0
500	2.6	5.4	8.0	10.7
750	3.4	6.8	10.2	13.6

Example. Consider a 24-mile log haul using "off highway" trucks over the following road conditions:

Section	Length	Standard of road	Alinement	Surface	Grade in direction of load
	Miles				*Percent*
1	14	Double lane	Excellent	Paved	−0.5
2	4	do	do	do	+3.0
3	4	Single lane with ditch	Fair	Gravel	−7.0
4	2	Single lane without ditch	Poor	Dirt	+5.0

Cost of delay time per M bd. ft. = $1.19.

To determine hauling cost per M bd. ft.:

Section	Length	Cost per M bd. ft. per mile	Cost per section
	Miles	*Dollars*	*Dollars*
1	14	0.117	1.638
2	4	.203	.812
3	4	.251	1.004
4	2	.435	.870
Total	24	1.006	4.324
Cost of delay time			1.190
Total hauling cost per M bd. ft.			6.180

Type of haul	Cost index 1959	1960	1961
Oversize "off highway," 7.5-10 M bd. ft.	1.05		

TABLE 14.—*Approximate log hauling costs per M bd. ft. per round trip mile for "on highway" trucks, Eastern United States, 1952* [1]

Class of road [2]	Percent of grade in direction of load: +10	+9	+8	+7	+6	+5	+4	+3	+2	+1
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
1. Double lane:										
A. Excellent alinement:										
1. Paved	0.458	0.423	0.380	0.350	0.325	0.280	0.244	0.209	0.187	0.163
2. Crushed gravel	.515	.477	.437	.405	.366	.331	.298	.263	.242	.217
B. Good alinement:										
1. Paved	.458	.423	.380	.350	.325	.280	.244	.214	.192	.168
2. Crushed gravel	.515	.477	.437	.405	.366	.331	.298	.268	.244	.222
C. Fair alinement:										
1. Paved	.458	.423	.380	.350	.325	.280	.250	.228	.204	.190
2. Crushed gravel	.515	.477	.437	.405	.366	.331	.301	.280	.258	.239
2. Lane and one-half: [3]										
A. Excellent alinement:										
1. Paved	.458	.423	.380	.350	.325	.280	.250	.228	.204	.192
2. Crushed gravel	.515	.477	.437	.405	.366	.331	.301	.280	.258	.239
B. Good alinement:										
1. Paved	.458	.423	.380	.350	.325	.285	.258	.236	.215	.212
2. Crushed gravel	.515	.477	.437	.405	.366	.337	.315	.290	.266	.258
C. Fair alinement:										
1. Paved	.458	.423	.380	.355	.326	.301	.277	.255	.250	.250
2. Crushed gravel	.515	.477	.437	.410	.380	.358	.331	.307	.293	.293
3. Single lane with 3-foot ditch: [3]										
A. Excellent alinement:										
1. Crushed gravel	.515	.477	.437	.405	.366	.331	.307	.282	.260	.250
2. Coarse gravel and dirt	.552	.515	.480	.443	.407	.379	.345	.315	.293	.271
B. Good alinement:										
1. Crushed gravel	.515	.477	.437	.405	.374	.347	.310	.298	.276	.276
2. Coarse gravel and dirt	.552	.515	.480	.443	.412	.385	.358	.331	.309	.304
C. Fair alinement:										
1. Crushed gravel	.515	.477	.444	.415	.386	.361	.337	.315	.307	.307
2. Coarse gravel and dirt	.552	.515	.484	.454	.424	.402	.375	.348	.331	.331
D. Poor alinement:										
1. Crushed gravel	.526	.497	.472	.445	.415	.391	.369	.369	.369	.369
2. Coarse gravel and dirt	.562	.535	.510	.480	.453	.429	.402	.391	.391	.391
4. Single lane without ditch: [3]										
A. Good alinement:										
1. Coarse gravel and dirt	.552	.515	.480	.442	.412	.385	.361	.334	.310	.310
B. Fair alinement:										
1. Coarse gravel and dirt	.552	.515	.488	.459	.434	.407	.380	.355	.347	.347
C. Poor alinement:										
1. Coarse gravel and dirt	.576	.550	.525	.495	.467	.443	.416	.416	.416	.416
5. Ungraded woods road:										
1. Dirt surface, 5 m.p.h. avg	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09

Class of road [2]	0	−1	−2	−3	−4	−5	−6	−7	−8	−9	−10	−11	−12	−13	−14	−15
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
1. Double lane:																
A. Excellent alinement:																
1. Paved	0.149	0.149	0.149	0.149	0.163	0.182	0.196	0.212	0.231	0.250	0.266	0.282	0.302	0.322	0.340	0.356
2. Crushed gravel	.198	.195	.195	.195	.212	.230	.244	.260	.280	.298	.315	.341	.347	.366	.385	.401
B. Good alinement:																
1. Paved	.163	.163	.163	.163	.163	.182	.196	.212	.231	.250	.266	.282	.302	.322	.340	.356
2. Crushed gravel	.206	.206	.206	.206	.212	.230	.244	.260	.280	.298	.315	.341	.347	.366	.385	.401
C. Fair alinement:																
1. Paved	.190	.190	.190	.190	.190	.190	.198	.212	.231	.250	.266	.282	.302	.322	.340	.356
2. Crushed gravel	.236	.236	.236	.236	.236	.236	.244	.260	.280	.298	.315	.341	.347	.366	.385	.401
2. Lane and one-half: [3]																
A. Excellent alinement:																
1. Paved	.192	.192	.192	.192	.192	.192	.198	.212	.231	.250	.266	.282	.302	.322	.340	.356
2. Crushed gravel	.239	.239	.239	.239	.239	.239	.244	.260	.280	.298	.315	.341	.347	.366	.385	.401
B. Good alinement:																
1. Paved	.212	.212	.212	.212	.212	.212	.212	.215	.231	.250	.266	.282	.302	.322	.340	.356
2. Crushed gravel	.258	.258	.258	.258	.258	.258	.258	.260	.280	.298	.315	.341	.347	.366	.385	.401
C. Fair alinement:																
1. Paved	.250	.250	.250	.250	.250	.250	.250	.250	.250	.252	.266	.282	.302	.322	.340	.356
2. Crushed gravel	.293	.293	.293	.293	.293	.293	.293	.293	.293	.298	.315	.341	.347	.366	.385	.401
3. Single lane with 3-foot ditch: [3]																
A. Excellent alinement:																
1. Crushed gravel	.250	.250	.250	.250	.250	.250	.250	.260	.280	.298	.315	.341	.347	.366	.385	.401
2. Coarse gravel and dirt	.271	.271	.271	.271	.271	.271	.271	.290	.306	.325	.342	.360	.377	.399	.415	.434
B. Good alinement:																
1. Crushed gravel	.276	.276	.276	.276	.276	.276	.276	.276	.280	.298	.315	.341	.347	.366	.385	.401
2. Coarse gravel and dirt	.304	.304	.304	.304	.304	.304	.304	.304	.306	.325	.342	.360	.377	.399	.415	.434
C. Fair alinement:																
1. Crushed gravel	.307	.307	.307	.307	.307	.307	.307	.307	.307	.307	.315	.341	.347	.366	.385	.401
2. Coarse gravel and dirt	.331	.331	.331	.331	.331	.331	.331	.331	.331	.331	.342	.360	.377	.399	.415	.434
D. Poor alinement:																
1. Crushed gravel	.369	.369	.369	.369	.369	.369	.369	.369	.369	.369	.369	.369	.369	.369	.385	.401
2. Coarse gravel and dirt	.391	.391	.391	.391	.391	.391	.391	.391	.391	.391	.391	.391	.391	.399	.415	.434
4. Single lane without ditch: [3]																
A. Good alinement:																
1. Coarse gravel and dirt	.310	.310	.310	.310	.310	.310	.310	.310	.310	.325	.342	.360	.377	.399	.415	.434
B. Fair alinement:																
1. Coarse gravel and dirt	.347	.347	.347	.347	.347	.347	.347	.347	.347	.347	.347	.360	.377	.399	.415	.434
C. Poor alinement:																
1. Coarse gravel and dirt	.416	.416	.416	.416	.416	.416	.416	.416	.416	.416	.416	.416	.416	.416	.418	.434
5. Ungraded woods road:																
1. Dirt surface, 5 m.p.h. avg	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09

[1] Based on 8-month hauling season; 10 pounds per board foot; average load, 1.84 M bd. ft.; delay or standby cost per M bd. ft., $1.54.
[2] Alinement factor:

$$\text{Excellent} = \frac{\textit{Average radius}}{\textit{No. of curves per mile}} = \text{over } 100$$

Good = do. = 50 to 100
Fair = do. = 20 to 50
Poor = do. = less than 20

[3] On single-lane or lane-and-one-half roads, increase the cost for time lost in passing vehicles on turnouts by the percent shown in following tabulation. Consider all vehicles for single-lane roads and only trucks for lane-and-one-half roads.

Turnout spacing (feet)	Increased cost when number of vehicles passing over road per hour is—			
	5	10	15	20
	Pct.	*Pct.*	*Pct.*	*Pct.*
250	0.8	1.5	2.3	3.0
500	1.1	2.2	3.3	4.4
750	1.5	2.9	4.1	6.0

Example. Consider a 24-mile log haul using "on highway" trucks over the following road conditions

Section	Length	Standard of road	Alinement	Surface	Grade in direction of load
	Miles				*Percent*
1	14	Double lane	Excellent	Paved	−0.5
2	4	do	do	do	+3.0
3	4	Single lane with ditch	Fair	Gravel	−7.0
4	2	Single lane without ditch	Poor	Dirt	+5.0

Cost of delay time per M bd. ft. = $1.54.

To determine hauling cost per M bd. ft.:

Section	Length	Cost per M bd. ft. per mile	Cost per section
	Miles	*Dollars*	*Dollars*
1	14	0.149	2.086
2	4	.209	.836
3	4	.293	1.172
4	2	.443	.886
Total	24	1.094	4.980
Cost of delay time			1.640
Total hauling cost per M bd. ft.			6.520

NOTE.—If actual weight of logs is 9,500 lbs. per M bd. ft., multiply the cost derived from table by 0.950, giving a total hauling cost per M bd. ft. per mile of $6.52×0.95= $6.194.

If product hauled is pulpwood weighing 5,500 lbs. per cord, the cost would be $6.52× .550=$3.586 per cord.

METHOD OF CALCULATING A COST INDEX

A current and reasonably accurate cost index for any specific size of truck can be determined by using the cost data for major items in a recent year. Table 15 shows the cost of such items in 1957 and 1952. The proportion of total cost for each of these items will vary somewhat with speed, road surface, and length of haul. However, for average conditions table 16 is sufficiently accurate. The use of tables 15 and 16 in determining a cost index for any size of truck and for a current year is demonstrated in Examples 5 and 6.

Example 5. Determining Cost Index for 60,000- to 86,000-Pound G.V.W. Truck and Trailer

$$\frac{\text{Cost of new truck and trailer now}}{\text{Cost of new truck and trailer in 1957}} \quad \frac{23,120}{21,609} \times 33.6 = 36.0$$

$$\frac{\text{Wages of driver now}}{\text{Wages of driver in 1957}} \quad \frac{2.44}{2.32} \times 34.8 = 36.6$$

$$\frac{\text{Cost of new set of tires now}}{\text{Cost of new set of tires in 1957}} \quad \frac{2,730}{2,660} \times 8.8 = 9.0$$

$$\frac{\text{Cost of gallon of fuel now}^{1}}{\text{Cost of gallon of fuel in 1957}^{1}} \quad \frac{.230}{.222} \times 6.5 = 6.7$$

83.7 88.3

$$\text{1959 cost index, "off highway"} \quad \frac{88.3}{83.7} = 1.05$$

[1] Includes Federal fuel tax of 3 cents per gallon.

Example 6. Determining Cost Index for 103,000- to 122,000-Pound G.V.W. Truck and Trailer

$$\frac{\text{Cost of new truck and trailer now}}{\text{Cost of new truck and trailer in 1957}} \quad \frac{33,100}{31,000} \times 36.0 = 38.4$$

$$\frac{\text{Wages of driver now}}{\text{Wages of driver in 1957}} \quad \frac{2.44}{2.32} \times 30.6 = 32.2$$

$$\frac{\text{Cost of new set of tires now}}{\text{Cost of new set of tires in 1957}} \quad \frac{4,780}{4,673} \times 10.3 = 10.5$$

$$\frac{\text{Cost of gallon of fuel now}^{1}}{\text{Cost of gallon of fuel in 1957}^{1}} \quad \frac{(.230)}{(.222)} \times 7.5 = 7.8$$

84.4 88.9

$$\text{1959 cost index, "off highway"} \quad \frac{88.9}{84.4} = 1.05$$

[1] Includes Federal fuel tax of 3 cents per gallon.

Although the above method results in a cost index based on a percentage of costs less than the whole—in Example 5, 83.7 percent, and in Example 6, 84.4 percent—it is assumed that an increase in the remaining percentage will be in about the same proportion.

The cost index relates to the 1957 study in which no allowance was made for State fuel tax or P.U.C. fees. It is for "off highway" costs only and is applied directly to the values taken from table 12, p. 34. Note that index values for 1959 are shown at the bottom of the table for both "off highway" and "on highway" costs.

TABLE 15.—*Cost of major items in truck operation, Western United States—1957, and Eastern United States—1952*

WESTERN UNITED STATES

G.v.w. (pounds)	Load	Tires	Tire size	Truck and trailer, less tires	Set of tires	Wages of driver	Fuel[1] Gas	Fuel[1] Diesel
	M ft. b. m.	*Number*		*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
50,000–60,000	5.40	18	9 x 20	13,900	2,005	2.32	0.222	0.16
60,000–86,000	6.97	18 18	10 x 20 10 x 20	21,609	2,519 2,660	2.32	.222	.16
86,000–103,000	8.60	18 18	11 x 22 11 x 24	25,300	3,130 3,824	2.32	.222	.16
103,000–122,000	10.07	18	12 x 24	31,000	4,673	2.32	.222	.16
122,000–164,000	14.00	2 16	12 x 24 14 x 24	38,100	8,300	2.32	.222	.16
164,000–207,000	18.20	2 8 8	12 x 24 14 x 24 16 x 24	43,400	10,300	2.32	.222	.16

EASTERN UNITED STATES

G.v.w. (pounds)	Load	Tires	Tire size	Truck and trailer, less tires	Set of tires	Wages of driver	Fuel[1] Gas	Fuel[1] Diesel
	M ft. b. m.	*Number*		*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
28,400	1.80	10	8.25 x 20	2,920	980	1.25	0.23	----------
34,700	2.30	10	9 x 20	3,615	1,175	1.25	.23	----------

[1] State tax excluded in Western United States costs, but included in those for Eastern United States.

TABLE 16.—*Proportion of total cost of major items in truck operation, based on average hauling conditions, Western United States—1957, and Eastern United States—1952*

WESTERN UNITED STATES

G.v.w. (pounds)	Load	Amortization of truck and trailer plus repair parts	Wages of driver and mechanic	Tires	Fuel and lubrication [1]	Miscellaneous costs
	M ft. b. m.	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
50,000 to 60,000	5. 4	25. 8	35. 9	9. 06	10. 4	18. 9
60,000 to 86,000	6. 4	33. 6	34. 8	8. 8	6. 5	16. 3
86,000 to 103,000	8. 6	34. 1	32. 3	10. 3	7. 2	16. 2
103,000 to 122,000	10. 1	36. 0	30. 6	10. 3	7. 5	15. 7
122,000 to 164,000	14. 0	36. 0	27. 7	13. 2	7. 6	15. 5
164,000 to 207,000	18. 2	36. 2	26. 2	13. 4	8. 7	15. 5

EASTERN UNITED STATES

G.v.w. (pounds)	Load	Amortization of truck and trailer plus repair parts	Wages of driver and mechanic	Tires	Fuel and lubrication [1]	Miscellaneous costs
	M ft. b. m.	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
28,400	1. 8	14. 9	36. 5	23. 0	11. 9	13. 7
34,700	2. 2	16. 2	34. 2	23. 6	12. 6	13. 4

[1] State tax excluded in Western United States costs, but included in those for Eastern United States.

GENERALIZED CONCLUSIONS

Diesel Versus Gasoline Trucks

There is small difference between the cost of hauling with gasoline-powered trucks and hauling with diesel-powered trucks. The higher repair, lubrication, and fixed costs of diesels counterbalance their advantage of lower fuel cost.

Size of Hauling Unit

The amount of saving in hauling cost that results from the use of heavy equipment rather than light must be determined for the specific job. In general, however, hauling cost decreases with an increase in the size of equipment used. This decrease is more apparent in short hauls and in hauls over slow roads.

It is probable that the total cost of getting out logs (hauling cost plus road costs) is favored in most instances by the use of trucks in the 60,000- to 80,000-pound class. Such trucks, with 8-foot bunks, would require the least revision in road and bridge design. Also, fixed and repair costs are relatively low for these trucks, since parts are produced in fairly large quantities.

Advantage of Paving

There are indications that paving or binding and smoothing a road surface may result in greater savings in hauling costs than can be realized by increasing truck size, which increases road construction costs.

Effect of Grade

Many conservative operators limit the grade of main and secondary roads to 3 percent for adverse grades and 8 percent for favorable. From the standpoint of hauling cost, it appears that economies can be effected in some instances by resorting to steeper grades. Consider a case where there is a choice of constructing a road with a grade of 5 percent for a distance of 2 miles, or of putting in a switchback, reducing the grade to 2.5 percent, and consequently lengthening the road distance to 4 miles. Assuming that the logging trucks will have a ratio (B) of effective horsepower to g.v.w. (in thousands of pounds) equal to 1.9 and that the road is gravel surfaced, the time factors from figures 5 and 6, pp. 7–8, are as follows:

"On highway" B=1.9 loading	*Plan 1*	*Plan 2*
Length of road section, miles	2	4
Grade, percent	5	2. 5
Time per mile, loaded, minutes	5. 75	3. 75
Time per mile, empty, minutes	2. 00	1. 40
Time per round trip mile, minutes	7. 75	5. 15
Total time for section, minutes	15. 50	20. 60

This would indicate that for conditions requiring additional distance to gain elevation, steeper grades are more economical than lighter ones. This is undoubtedly true up to the point where tractive resistance cannot be successfully applied because of slipping or icy conditions on the road, or where the shock induced by shifting gears on adverse grade begins to cause excessive mechanical failure of the vehicle. For spur roads, where hauling is done during the dry summer months, a steeper grade could undoubtedly be used.

Effect of Undulating Grade

The determination of speeds obtained on undulating grades presents a rather complicated problem. On a slightly rolling grade, speed is not very different from that on a uniform grade. However, as the length between breaks in grade increases and the grade increases, the average speed approaches more nearly the average speed obtained for a sustained adverse followed by a sustained favorable grade.

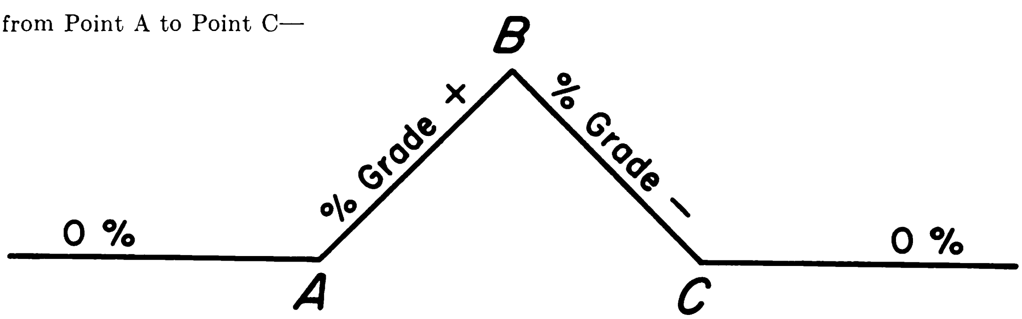
Table 17 shows the approximate speed of travel over a break in a zero-percent grade for various lengths of hump and steepness of hump. This table was compiled for a gravel-surfaced road as an indication of time lost because of breaks in grade.

TABLE 17.—*Average speed of loaded truck (B=1.75) on rolling grades,*[1] *gravel-surfaced road*

Grade (percent)	Distance between break in grade in feet (A to B & B to C)						
	200	300	400	500	600	700	800
	M.p.h.	*M.p.h.*	*M.p.h.*	*M.p.h.*	*M.p.h.*	*M.p.h.*	*M.p.h.*
0	29. 26	29. 26	29. 26	29. 26	29. 26	29. 26	29. 26
1	28. 81	28. 62	28. 36	28. 26	27. 79	27. 84	27. 71
2	28. 41	27. 99	27. 69	27. 01	26. 96	26. 54	26. 26
3	27. 81	27. 16	26. 21	25. 84	25. 29	24. 89	24. 11
4	27. 34	26. 19	25. 29	24. 69	23. 94	23. 31	22. 99
5	26. 84	25. 51	24. 16	22. 51	21. 41	20. 51	19. 96
6	25. 77	24. 07	22. 27	20. 57	19. 68	18. 47	18. 22

[1] Speed on level surface without break in grade is 29.26 m.p.h.

Average speed from Point A to Point C—



Effect of Alinement and Roadway Width

The effect of alinement on speed is more apparent for single-lane roads than for double lane. This factor is of considerable importance on narrow roads with favorable grades.

On single-lane roads and lane-and-one-half roads, the factor governing speed around curves is sight distance. The wider the road, the greater the sight distance; consequently, the permissible speed is greater. Anything that increases sight distance will increase speed.

On double-lane roads, the factor governing speed is slippage due to centrifugal force.

The speed on single-lane roads may be increased by double laning the curves.

Except as it affects speed on curves, the effect of roadway width is not appreciable.

Need for Correlation of Alinement and Grade

There is nothing to be gained in improving the alinement of a road where speed is already controlled by steepness of grade. However, in some situations a saving in hauling cost can be had by increasing speed through a better correlation of alinement and grade. For example, a road over somewhat broken terrain is sometimes located so as to use a level grade from a ridge into the next draw, a steep grade of about +10 percent to climb to the next ridge, a level grade into the next draw, and so forth for each succeeding ridge and draw.

The slope of ridges and draws in such terrain is about 30 percent. Thus located, the road is slightly shorter than a road with a 5-percent sustained grade, but the decrease in length is negligible. Such a road reduces speed considerably for both empty and loaded trucks. Usually the alinement is satisfactory for about a 22 m.p.h. speed.

Consider a section of this road with a level grade one-half mile long into a draw and another section a half mile long to the next ridge on 10-percent grade. The grade is favorable to loaded trucks. The time required for the loaded truck would be 1.62 minutes on the 10-percent favorable grade and 1.36 minutes (limited by alinement) on the level grade, or a total of 2.98 minutes for the entire mile. The time for the empty truck would be 1.36 minutes (limited by alinement) on the level grade and 1.92 minutes on the 10-percent adverse grade, or a total of 3.28 minutes for the entire mile.

The round-trip time, under this condition, would be 2.98+3.28, or 6.26 minutes. If a 5-percent grade were used instead of the 10-percent grade, the time would be 2.72 minutes for the loaded truck and 2.72 minutes for the empty, or a total of 5.44 minutes per round-trip mile, the trip both ways being limited by alinement.

Assume a 30-mile haul over gravel road and an 8-month hauling season, using trucks that haul 5 M bd. ft. per load. In dollars and cents, the 10-percent road location would cost $0.2024 per M bd. ft. per mile. The 5-percent road location for the same condition would cost $0.1848, thus effecting a saving of $0.0176 per M bd. ft. per mile. (See fig. 18, top, p. 26.) If 100,000 M bd. ft. of lumber were hauled over this road, the saving would be $1,760 per mile of road.

Speed could be increased still further, in a case of this kind, by steepening the road downhill from the curves in the direction of haul and leveling off a proportionate amount on the uphill side. This would not only allow the loaded truck to brake itself in a shorter distance when entering a curve, but would also allow it to accelerate faster after rounding the curve. The same thing would be true of the empty truck on the return trip.

SYMBOLS AND ABBREVIATIONS

A=Projected frontal area of vehicle and load in square feet.
a=Acceleration in feet per second, per second.
B=Ratio of effective engine horsepower to gross vehicle weight in thousands of pounds.
C=Costs which occur when vehicle is actually hauling logs, on a per-minute basis.
D=Cost of tires on a per-mile basis.
d.i.b.=Diameter inside bark.
E=Ratio between output horsepower and rated horsepower.
F=Force required to move vehicle, in pounds.
f=Side-skidding factor (usually 0.16 for hard, smooth surfaces).
G=Grade expressed as a ratio of vertical rise to horizontal distance.
g.v.w.=Gross vehicle weight in pounds, weight of vehicle plus load (if any).
hp.=Rated horsepower of engine.
J=Costs which occur during nonoperating periods; i.e., fixed costs, on a per-minute basis.
K=Air resistance coefficient.
L=Length of total haul in miles from loading station to dump.
$l.w.$=Light weight of vehicle in pounds.
M=One thousand board feet.
N=Costs which occur when driver is on truck but not hauling logs; i.e., cost of delay time on a per-minute basis.
P=Total power required to move vehicle in foot-pounds per second.
P_g=Power required to overcome grade (gravity) in foot-pounds per second.
P_r=Power required to overcome rolling resistance in foot-pounds per second.
P_a=Power required to overcome air resistance in foot-pounds per second.
Q=Total load on vehicle in thousand board feet of timber.
R=Rolling resistance coefficient.
r=Radius of curvature in feet.
S=Distance in feet.
s=Superelevation in feet per foot of roadway width.
T=Total hauling time per round trip (does not include delay time).
t=Time per round-trip mile.
V=Velocity of vehicle in feet per second.
v=Velocity in miles per hour.
W=Gross vehicle weight (same as g.v.w.) of vehicle plus load, if any, in pounds.
Y=Operating season in months.
Z=Delay time per thousand board feet per round trip.

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APPENDIX 1. TRAVEL TIME FACTORS

A. *Travel Time as Controlled by Grade, Rolling Resistance, and Air Resistance*

1. *Power Required*

The power required to move a vehicle along a road is made up of the following components:

(a) P_g=Power to overcome gravity (grade resistance).
(b) P_r=Power to overcome rolling resistance.
(c) P_a=Power to overcome air resistance.

The total power required to move the vehicle can then be stated as:

$$P=P_g+P_r+P_a$$

a. *Power required to overcome gravity*

The force exerted by gravity against a vehicle is the component of the weight of the vehicle which is parallel to the grade. This component is the weight multiplied by the percent of grade (ratio of vertical rise to horizontal distance) or $F_g=WG$.

The power required to move a vehicle against this grade is the product of the force times the velocity or $P_g=F_gV=WVG$.

b. *Power required to overcome rolling resistance*

Rolling resistance depends on road surface characteristics, type and condition of tires, and friction of wheel bearings. From tests conducted by the various highway departments and engineering schools, this force has been determined to be very nearly constant for all speeds, and for any one surface type it can be expressed as a coefficient corresponding to an adverse percent of grade. If this coefficient is R, the force to overcome rolling resistance becomes $F_r=WR$, and the required power to overcome it at any given velocity becomes $P_r=F_rV=WRV$.

c. *Power required to overcome air resistance*

The molecular impact causing normal air pressure is assumed to be the same on all sides of an object that is not in motion. When it is in motion, there is an increased pressure on the front and a decreased pressure on the rear. Since the streamline effect of the average logging truck is practically nil, the frontal surface can, for practical purposes, be assumed to be at right angle to the direction of travel.

The increased impact in the direction of travel on the frontal area of the truck may then be given as

$$f=\tfrac{1}{2}\frac{w}{g}V^2$$

where f is the force acting against the front of the truck, w is the weight of air per cubic foot in pounds, g is 32.2 feet/second/second and V is the velocity of the truck in feet per second. The decreased impact in the direction of travel on the rear of the truck will also be

$$f=\tfrac{1}{2}\frac{w}{g}V^2$$

Therefore, the total force to overcome air resistance will be

$$F_a=2\left(\tfrac{1}{2}\frac{w}{g}V^2\right)=\frac{w}{g}V^2$$

The weight of air can be determined by the following equation taken from "Kent's Mechanical Engineers' Handbook":

$$w=\frac{1.325\times b}{459.6+t}$$

where b is the barometric pressure in inches and t is the temperature in degrees Fahrenheit.

For the purpose of this study, the barometric pressure will be taken as 27.7 inches, which is normal for a 2,000-foot altitude. This is about the average altitude for logging operations in the Northwest. The temperature will be assumed to be 70° F.

Then $$w=\frac{1.325\times 27.7}{459.6+70}=0.0692$$
pounds per cubic foot.

In equation (1), $\frac{w}{g}$ can then be represented as a constant

$$k=\frac{w}{g}=\frac{0.0692}{32.2}=0.00215$$

This agrees closely with the value of 0.0021 recommended by R. G. Paustian in Iowa State College of Engineering Extension Department Bulletin 119 in 1934.

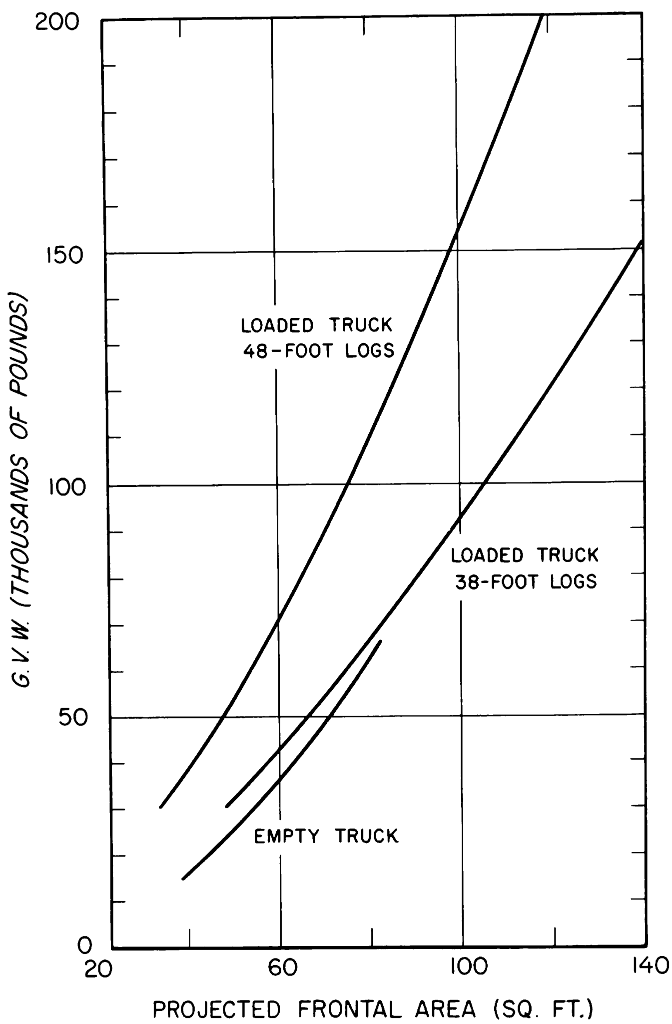

FIGURE 22.—Projected frontal area of loaded and empty trucks.

Equation (1) then becomes

$$F_a=0.00215\ AV^2 \qquad (2)$$

The power required to overcome the resistance is the product of the force times the velocity or

$$P_a=F_aV=kAV^3 \qquad (3)$$

Figure 22 shows the approximate frontal areas for loaded and empty trucks. These data are based on field measurements.

d. *Total power required*

The total power required $P=P_g+P_r+P_a$ then becomes $P=WGV+WRV+KAV^3$ (4)

2. *Power Available*

The effective power that pushes a vehicle along a road is the net power output of the engine less power losses between the engine and the tires. If the ratio between rated power and effective horsepower is represented as a factor, E, and since one horsepower equals 550 foot-pounds per second, the net power available expressed in foot-pounds per second is $HP\times E\times 550$. When the engine is operating at maximum output, the speed obtained is that at which required power equals available power. Equation (4) then becomes

$$HP\times E\times 550=WGV+WRV+KAV^3 \qquad (5)$$

3. *Ratio of Rated Horsepower to Effective Horsepower*

Since in the field tests all of the values in equation (5) are known except E and R, it is possible to set up pairs of equations for different conditions over the same type of surface and find the values for E and R simultaneously. In using this method, it is essential that neither of the test road sections have alinement or other factors that will reduce the speed below the maximum which the engine can produce on that type surface. An example of this solution follows:

Test Section No. 1—Compacted gravel surface, ¾-inch minus

Empty truck: $HP=175$
$W=31{,}770$ pounds
$V=16.6$ feet per second
$G=+11.3$ percent
$K=0.00215$
$A=56$ square feet

Test Section No. 2—Compacted gravel surface, ¾-inch minus

Loaded truck: $HP=175$
$W=90{,}548$ pounds
$G=+0.80$ percent
$K=0.00215$
$V=28.4$ feet per second
$A=70.5$ square feet

Using equation (5), $HP\times E\times 550=WVG+WVR+KAV^3$ and substituting the values from Test Section No. 1, we have

$$175\times E\times 550=31{,}770\times 16.6\times 0.113+31{,}770\times 16.6\times R+0.00215\times 56\times (16.6)^3$$

or $96{,}250=59{,}594+527{,}382R+554.$

Also substituting the values from Test Section No. 2 in equation (5), we have

$$175\times E\times 550=90{,}548\times 28.4\times 0.008+90{,}548\times 28.4\times R+0.00215\times 70.5\times (28.4)^3$$

or $96{,}250E=20{,}572+2{,}571{,}563R+3{,}472.$

Solving simultaneously with equations from Test Section No. 1, we have

$$\begin{aligned} 96{,}250E&=59{,}594+527{,}382R+554\\ \underline{96{,}250E}&\underline{=20{,}572+2{,}571{,}563R+3{,}472}\\ 0&=39{,}022-2{,}044{,}181R-2{,}918\\ R&=0.0180\\ E&=0.7230 \end{aligned}$$

Table 18 gives the field condition and corresponding values of E for each pair of field tests considered.

TABLE 18.—*Values of E for each pair of field tests considered* [1]

Test section	*HP*	*W*	*G*	*A*	*V*	Loaded or empty	Surface type	*R*	*E*
		Pounds	*Percent*	*Square feet*	*Feet per second*				
1	175	31, 770	+11. 30	56. 0	16. 60	Empty	(¾-in. gravel)	0. 0180	0. 723
2	175	90, 548	+0. 80	70. 5	28. 40	Loaded			
3	175	31, 770	+10. 20	56. 0	17. 20	Empty	(¾-in. gravel)	. 0189	. 693
4	175	90, 548	−0. 55	70. 5	44. 20	Loaded			
5	175	31, 770	+9. 00	56. 0	19. 35	Empty	(¾-in. gravel)	. 0163	. 693
6	175	90, 548	−0. 54	70. 5	48. 00	Loaded			
7	200	39, 000	+0. 35	62. 5	59. 00	Empty	(Compacted dirt)	. 0175	. 689
8	200	117, 000	+2. 71	117. 0	14. 40	Loaded			
9	200	39, 000	+5. 70	62. 5	27. 70	Empty	(¾-in. gravel)	. 0125	. 708
10	200	117, 000	−0. 33	117. 0	47. 50	Loaded			
11	138. 7	55, 022	+6. 30	51. 0	11. 90	Loaded	(Paved asphalt)	. 0145	. 688
12	130. 5	56, 080	−0. 38	51. 0	53. 70	Loaded			
13	265	38, 350	+10. 50	62. 0	20. 12	Empty	(2-in. gravel)	. 0226	. 683
14	265	92, 783	+1. 38	72. 0	28. 85	Loaded			
15	265	38, 350	+10. 70	62. 0	20. 20	Empty	(2-in. gravel)	. 0292	. 731
16	265	92, 783	+0. 27	72. 0	33. 95	Loaded			
Average									. 701

[1] The average elevation at which the field tests were made was 2,000 feet. The speeds, weights, and horsepower are the average of several trucks with one or more trips for each truck. Test trips over each section varied from 5 to 21.

In general, truck manufacturers have found that the effective horsepower output of an engine is reduced approximately 3 percent for each thousand feet of elevation above sea level. On this basis, the value of E used in this report for various elevations above sea level is shown in table 3, p. 4.

4. *Rolling Resistance*

Rolling resistance for various surface types may also be determined by using equation (5). By substituting known values from field tests in this equation, the value for R can be computed for various surface types. As an example, the following data from one test run are substituted in equation (5), and the value of R is computed:

Paved asphalt road

$HP=175$

$E=70$ percent

$W=90{,}548$ pounds

$G=0$ percent

$A=70.5$ square feet

$V=47.4$ feet per second

$$175\times 0.70\times 550=90{,}548\times 47.4\times 0+90{,}548\times 47.4\times R+0.00215\times 70.5\times (47.4)^3$$

$$67{,}375=0+4{,}291{,}975R+16{,}144$$

$$R=0.0119$$

Table 19 gives field for average weight, horsepower, and speed, and the resulting values for R obtained on several of the test sections on various surface types. In computing R, an average value of 0.70 was used for E.

Other isolated sections of the roads which were not well compacted or had weaving subgrades gave values for R up to 0.041. One section on which loose gravel had been placed and not compacted gave a value of 0.08.

5. *Speed on Adverse Grade*

By using the values of E from table 3, p. 4, and R from table 19, it is possible to compute the speed on any grade where power is the determining factor by solving equation (5), p. 46, for V. Because this is a cubical equation and involves a rather tedious computation to solve for V, two graphs were designed to provide quick solution (figs. 23 and 24). For example, to determine the speed over a 4-percent grade of a truck that has a net engine horsepower of 120, superimpose 120 (fig. 23) over the zero ordinate in figure 24; the curve of figure 23 intersects the 4-percent grade line of figure 24 at 14 m.p.h., the speed for that grade.

6. *Speed on Favorable Grade*

The speed at which a vehicle can safely descend a grade is apparently dependent upon—

(a) Steepness of grade
(b) Ratio of brake capacity to gross load
(c) Sight distance
(d) Roughness of road surface
(e) Height of center of gravity with relation to width between outside tires
(f) Personal element of driver

An equation that would include all of these items and yet be practical for general use would

TABLE 19.—*Values for R obtained on test sections of various surface types*

PAVED ASPHALT SURFACE

Test section	*HP*	*W*	*G*	*A*	*V*	Loaded or empty	*R*
		Pounds	*Percent*	*Square feet*	*Feet per second*		
17	175	90, 548	0. 00	70. 5	47. 4	Loaded	0. 0119
18	175	90, 548	—. 20	70. 5	48. 9	do	. 0132
19	175	90, 548	—. 33	70. 5	50. 25	do	. 0139
20	130. 5	56, 080	—. 38	51. 0	53. 7	do	. 0149
21	160	67, 450	+5. 00	81. 0	14. 3	do	. 0133
22	104. 3	16, 000	+1. 20	40. 0	59. 86	Empty	. 0107
Average							. 0130

WELL-COMPACTED SMOOTH GRAVEL SURFACE, ¾-INCH MINUS

Test section	*HP*	*W*	*G*	*A*	*V*	Loaded or empty	*R*
		Pounds	*Percent*	*Square feet*	*Feet per second*		
23	175	90, 548	—0. 54	70. 5	48. 0	Loaded	0. 0170
24	175	90, 548	+. 80	70. 5	28. 4	do	. 0168
25	175	90, 548	—. 55	70. 5	44. 2	do	. 0191
26	175	31, 770	+10. 20	56. 0	17. 2	Empty	. 0202
27	175	31, 770	+9. 00	56. 0	19. 34	do	. 0182
28	200	39, 000	+. 35	62. 5	59. 00	do	. 0180
Average							. 0182

FAIRLY WELL-COMPACTED GRAVEL SURFACE, 2-INCH MINUS

Test section	*HP*	*W*	*G*	*A*	*V*	Loaded or empty	*R*
		Pounds	*Percent*	*Square feet*	*Feet per second*		
29	265	92, 783	+0. 27	72	33. 95	Loaded	0. 0277
30	265	92, 783	+1. 38	72	28. 85	do	. 0235
31	265	92, 783	+10. 5	62	20. 12	Empty	. 0258
Average							. 0257

WELL-COMPACTED DIRT ROADS (NATIVE ROCK AND CLAY MIXTURE)

Test section	*HP*	*W*	*G*	*A*	*V*	Loaded or empty	*R*
		Pounds	*Percent*	*Square feet*	*Feet per second*		
32	175	90, 548	+4. 00	70. 5	11. 88	Loaded	0. 0224
33	175	90, 548	+3. 25	70. 5	13. 75	do	. 0213
34	200	117, 400	—. 59	117. 0	34. 67	do	. 0224
35	200	31, 100	+6. 08	56. 0	29. 27	Empty	. 0205
36	200	31, 100	+9. 06	56. 0	21. 23	do	. 0243
37	200	31, 100	+5. 67	56. 0	30. 48	do	. 0209
Average							. 0220

WELL-COMPACTED DIRT ROADS (ALL DIRT, NO ROCKS)

Test section	*HP*	*W*	*G*	*A*	*V*	Loaded or empty	*R*
		Pounds	*Percent*	*Square feet*	*Feet per second*		
38	200	117, 000	+2. 31	117	16. 2	Loaded	0. 0173
39	200	117, 000	+2. 71	117	14. 4	do	. 0182
Average							. 0177

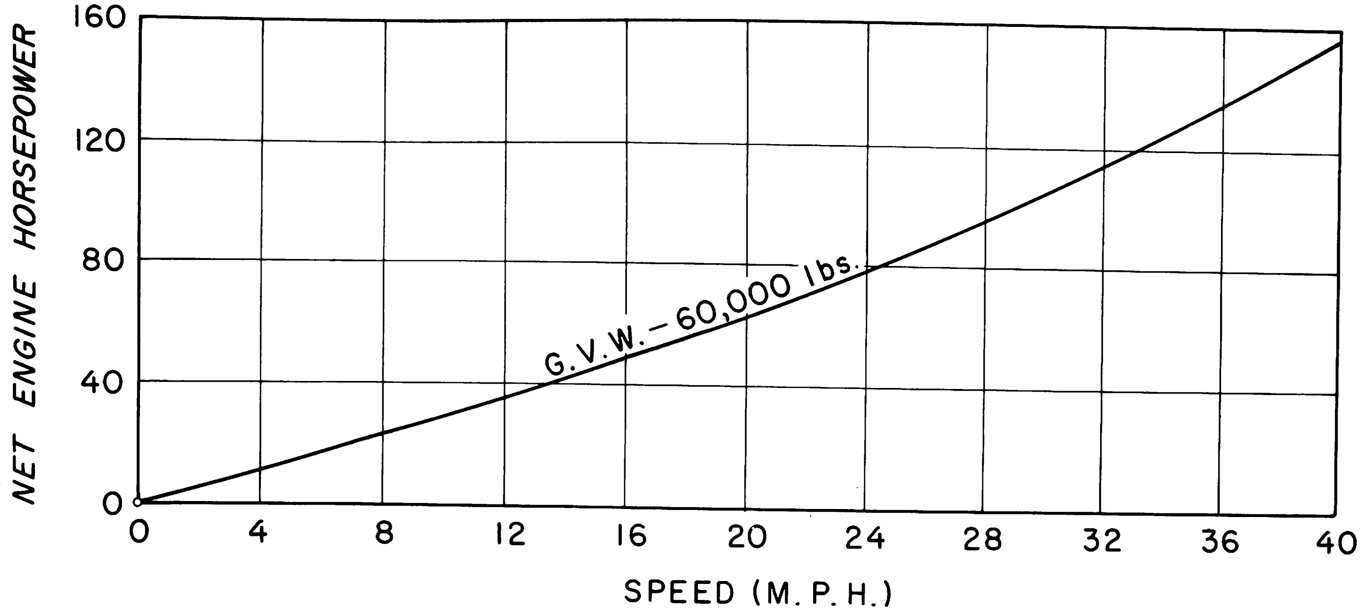

FIGURE 23.—Horsepower required to overcome air and rolling resistance (R=0.018; 60,000 lbs. g.v.w., 48-foot logs; gravel surface, ¾-in. minus).

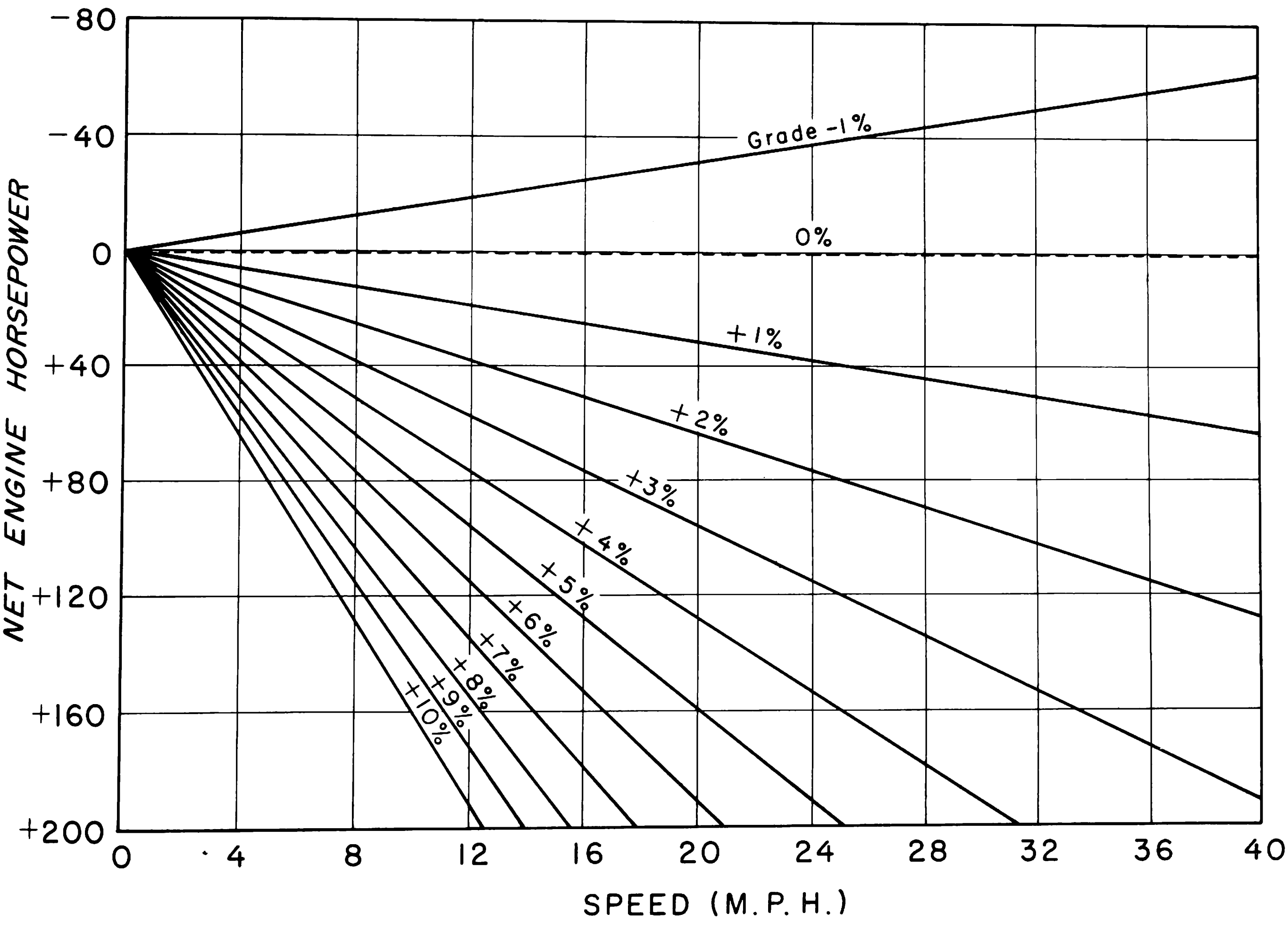

FIGURE 24.—Horsepower required to overcome grade resistance (60,000 lbs. g.v.w.).

be difficult to find. Therefore, the following empirical equation has been set up based on field observations:

$$V = \frac{2.4}{(0.03 - G)}$$

where V is the velocity in miles per hour and G is percent of grade.

The curve of this equation is shown in figure 25 with plotted points of actual speeds recorded in field tests. These points were selected in order to eliminate the effect of curvature as much as possible.

It was determined in field tests that the faster speeds were on sections where sight distance was the greatest and where the road was in a very smooth condition. It was also determined that an increased load for any given size of vehicle results in an almost proportional decrease in speed for the steeper grades.

There is no definite indication that speeds are greater on a paved road than on one of gravel or dirt, provided that the roads are all reasonably smooth.

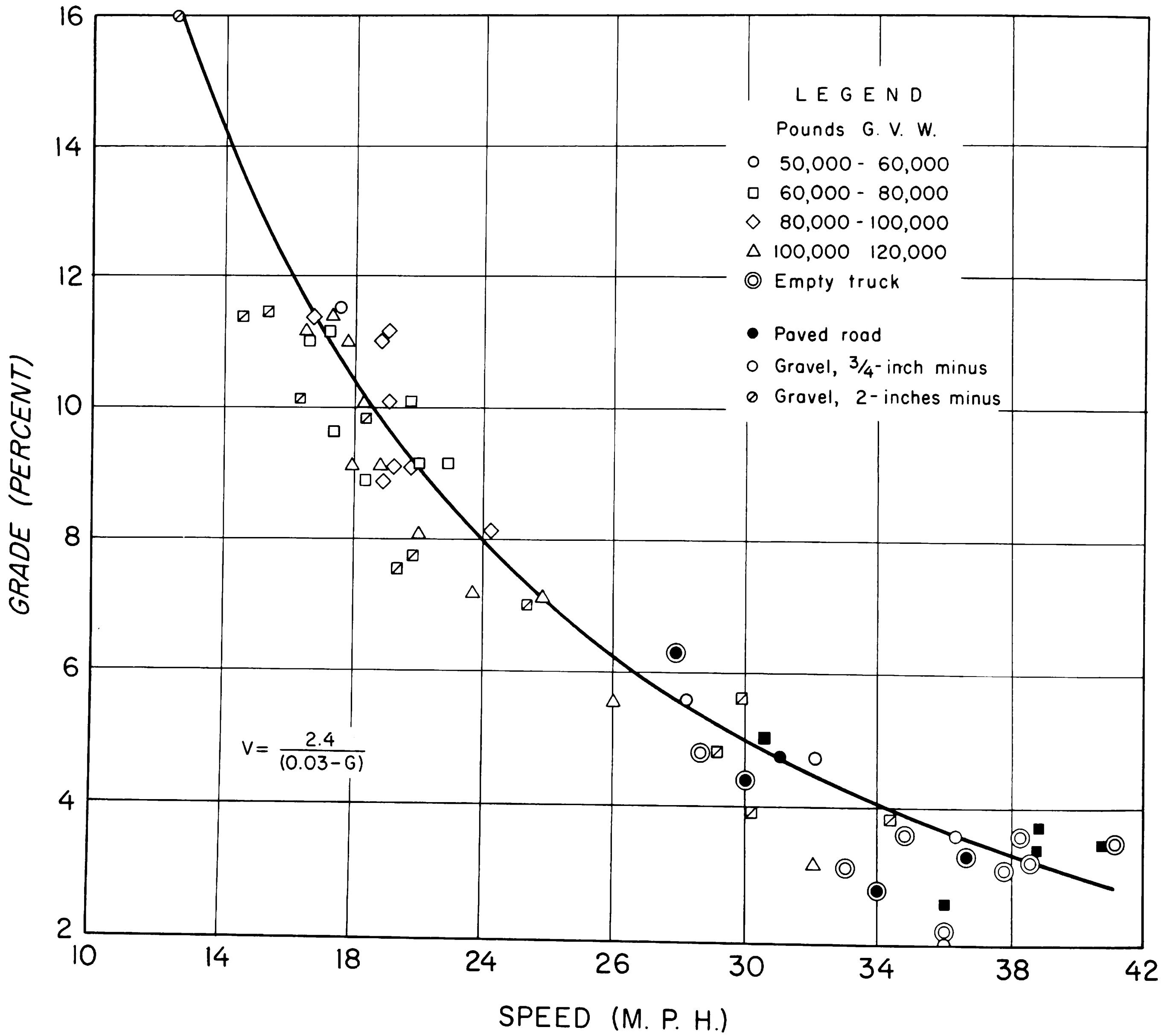

FIGURE 25.—Speed of trucks on descending grades.

7. *Maximum Speeds*

The maximum speed at which a truck will travel between the limits of adverse grade and safety on favorable grade, is determined by a variety of factors, including alinement, sight distance, and tire performance. Although the modern tires for on-highway and off-highway hauling perform adequately at the speeds for which they were designed, their performance is limited by the user's attention to specific conditions. The vehicle load must be properly placed so that each tire carries no more than its specified load; air pressure in tire must be maintained according to specifications; the wheel axle must be in proper alinement; and dual tires must be properly matched and spaced.

Maximum speeds used in developing time of travel charts in this study are consistent with present practice and with the highway speed limits generally in use in the Pacific Northwest. The limiting speeds in figures 3 through 8, "Effect of Grade on Travel Time," are as follows:

G.v.w.—loaded (pounds)	*Maximum speed (m.p.h.)*
Up to 86,000	45
86,000–122,000	35
122,000–164,000	30
Over 164,000	30
Empty trucks	50

8. *Calculation of Speed Versus Grade—Sustained Grades*

Relation of speed to grade was calculated according to the foregoing methods and considerations, and the results are shown on figures 3 to 8, inclusive. It will be noted that the symbol B is used to denote ratio of effective horsepower to gross vehicle weight in thousands of pounds.

$$B=\frac{HP\times E\times 1{,}000}{GVW} \tag{6}$$

Since the retarding effect of air resistance is less in proportion to horsepower available for larger trucks than it is for smaller trucks, there is a slight error in the curves for higher speeds, but the error is so small that it would be barely discernible on a graph.

9. *Acceleration or Deceleration Calculations*

Rate of acceleration or deceleration depends upon horsepower available for driving the vehicle, resistance of the vehicle (air, grade, and rolling), and weight of the vehicle plus the load. If we assume that the gear ratio permits full engine horsepower to be applied at any speed, the acceleration can be expressed as

$$a=32.2\frac{(HP\times E\times 550-WVG-WVR-0.0021AV^3)}{W\times V} \tag{7}$$

This equation does not take into account power required to set rotating parts of the vehicle in motion. However, the error so introduced is insignificant.

Figure 17 (top, p. 18) shows the accelerating distance between various speeds for several grades on gravel roads, using a ratio $B=1.75$. These curves were prepared by first determining the value of a by equation (7) for various grades and velocities. After a was determined, the time increment between succeeding points on the curve was found by dividing the change in velocity by the average value of a between the points considered. With the time increment known, the distance increment was found by multiplying the time increment by the average velocity between the points considered.

Figure 17 (bottom, p. 18) shows the decelerating distance between various speeds for several grades on gravel roads, using a ratio $B=1.75$. These curves were calculated by first determining the kinetic energy at several speeds and finding the energy increments between those speeds on the grade considered. This is the kinetic energy to be dissipated in decelerating down to each speed. Power required to propel the vehicle for the average speed during each deceleration period is also determined. Power in excess of that capable of being supplied by the truck is then found. The time for decelerating between various speeds is found by dividing the kinetic energy to be dissipated by the power in excess of that supplied by the truck. Distance traveled is found by multiplying time for the interval by average speed for the interval.

An example of the method used to compute decelerating effect on adverse grades is shown in the following tabulation for an 8-percent grade. This example is based on a 66,000-pound ground load and a 165-hp. engine with a 70-percent mechanical efficiency operating over a gravel road. Normal speed of such a truck on a sustained 8-percent grade is 6.67 m.p.h.

Approach speed (m.p.h.) (1)	Kinetic energy of approach speed (2)	△ Kinetic energy (3)	Average speed during deceleration (4)	Power required at average speed (5)	Less power of truck (63,500) (6)	Time required to use momentum (7)	Distance traveled (increment) (8)	Distance traveled (cumulative) (9)
	Foot-pounds	*Foot-pounds*	*Miles per hour*	*Foot-pounds per second*	*Foot-pounds per second*	*Seconds*	*Feet*	*Feet*
6. 67	98, 022							1, 325
		10, 064	6. 8	65, 169	1, 669	6. 03	60	
7. 0	108, 086							1, 265
		33, 336	7. 5	71, 508	8, 008	4. 16	46	
8. 0	141, 422							1, 219
		36, 893	8. 5	81, 133	17, 633	2. 09	26	
9. 0	178, 315							1, 193
		42, 232	9. 5	90, 719	27, 219	1. 55	22	
10. 0	220, 547							1, 171
		275, 456	12. 5	119, 793	56, 293	4. 89	90	
15. 0	496, 003							1, 081
		385, 581	17. 5	169, 100	105, 600	3. 65	94	
20. 0	881, 584							987
		496, 454	22. 5	219, 675	156, 175	3. 18	105	
25. 0	1, 378, 038							882
		605, 975	27. 5	271, 964	208, 464	2. 91	117	
30. 0	1, 984, 013							765
		716, 130	32. 5	326, 426	262, 926	2. 72	130	
35. 0	2, 700, 143							635
		827, 424	37. 5	383, 294	319, 794	2. 59	142	
40. 0	3, 527, 567							493
		936, 462	42. 5	443, 019	379, 519	2. 47	154	
45. 0	4, 464, 029							339
		1, 046, 628	47. 5	506, 076	442, 576	2. 36	164	
50. 0	5, 510, 657							175
		1, 158, 331	52. 5	572, 668	509, 168	2. 27	175	
55. 0	6, 668, 988							0

Column 3 gives the increment of kinetic energy to be dissipated between the various approach speeds. Column 6 gives the rate at which this kinetic energy is used at the average speed during the deceleration increment. Therefore, Column 3 divided by Column 6 gives the time involved in using up the momentum, shown in Column 7. Column 8 is the distance traveled during this time increment. Column 9 then gives a summation of these incremental distances from 55 m.p.h. to the sustained speed. Any speed could have been adopted for a calculation base; the intercepts of speed versus deceleration distance are the important features of the tabulation.

Figure 26 shows the distance required for acceleration of loaded and empty trucks on a 2-percent grade.

B. *Travel Time as Affected by Curvature and Alinement*

1. *Loss of Time Factors*

The loss in time caused by curvature is made up of the following components:

a. *Deceleration time loss*

Time lost while slowing down in order to negotiate a curve safely.

b. *Curve time loss*

Time lost while going around the curve.

c. *Acceleration time loss*

Time lost while accelerating to the speed that the grade will allow.

2. *Safe Speed on Curves*

a. *Double-lane roads*

The limit on safe speed around curves in double-lane roads is the speed at which side slipping will occur. This limit is based on the assumption that vehicles will be kept to the proper side of the road and that the road is otherwise unobstructed. The speed is given by the equation:

$$v=\sqrt{\frac{r(s+f)}{0.067}} \qquad (8)$$

where

v = safe speed in miles per hour
r = radius of curvature
s = superelevation in feet per foot roadway width
f = side-skid factor—usually about 0.16 for hard-compacted, smooth roads

Most logging roads are built with little or no superelevation in order to avoid side slipping

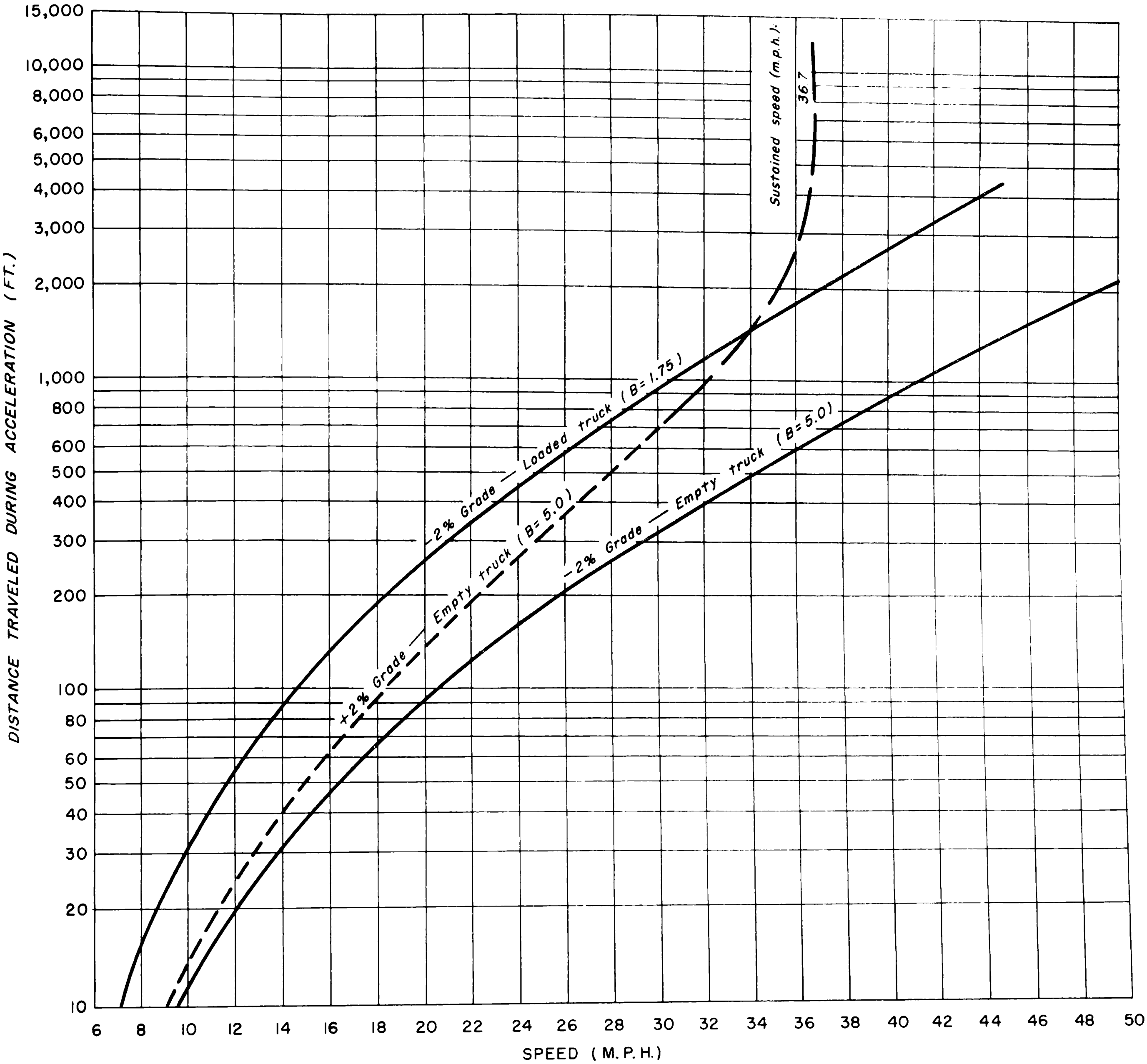

FIGURE 26.—Distance required for acceleration of loaded and empty trucks in the 60,000- to 86,000-pound class.

caused by icy conditions, particularly on adverse grades. For icy conditions, the above formula becomes

$$v=\sqrt{\frac{r(0.16+0)}{0.067}}$$

or

$$v=1.55\sqrt{r} \qquad (9)$$

Computations for double-lane roads used in this analysis are based on equation (9) for allowable speed on curves. For main highways that are normally superelevated to a maximum of 0.10 feet per foot of width, the safe speed on curves will be 30 percent greater than for roads not superelevated.

b. *Single-lane roads*

If the roadway is not wide enough to allow vehicles to pass each other, the safe speed is limited by the sight distance that permits two trucks approaching each other to stop without colliding, or one truck to stop without hitting an obstruction in the road.

Figure 27 gives the sight distance for any radius of curvature up to 2,000 feet for roads with 12-, 14-, and 20-foot widths. Sight distance is assumed to be limited by back slope on

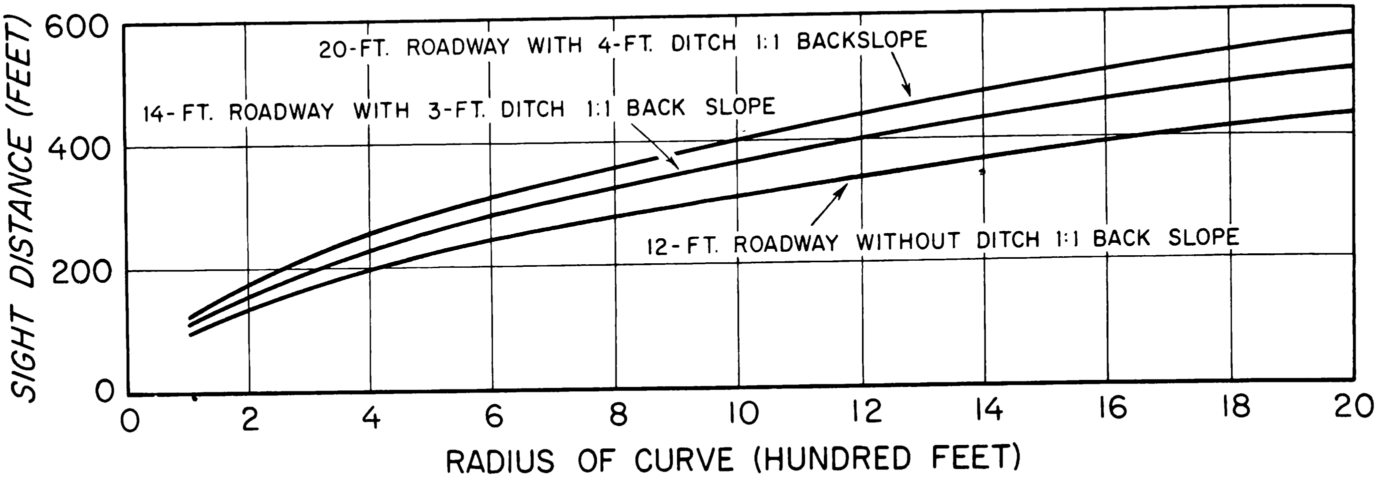

FIGURE 27.—Sight distance on horizontal curves.

the cut side of the road and by timber and brush at an equivalent distance from the centerline on the fill side of the road.

Distance required to stop a vehicle from a given speed on level grade is given by the equation.[2]

$$d=\frac{v^2}{30(f)}$$

where d is the braking distance, v is the speed in miles per hour, and f is the friction coefficient of the tire against the road; a value of $f=0.40$ is recommended as reasonably conservative. A reaction time of 3 seconds between sighting an obstacle and applying the brake has been found to be necessary. Sight distance required for each driver in order to stop would then be:

$$d=3\times v\times\frac{5{,}280}{3{,}600}+\frac{v^2}{30f}$$

The combined sight distance required for two drivers approaching each other would then be twice this amount, or

$$2d=8.8v+\frac{v^2}{15f}$$

The grade of the road does not affect this combined distance, because a favorable grade to one driver will be adverse to the other. Figure 28, based on this equation, shows the safe speed at which a vehicle can travel for sight distances up to 400 feet.

[2] Source: L. I. Hewes. Vol. 1 Amer. Highway Practice. 1942.

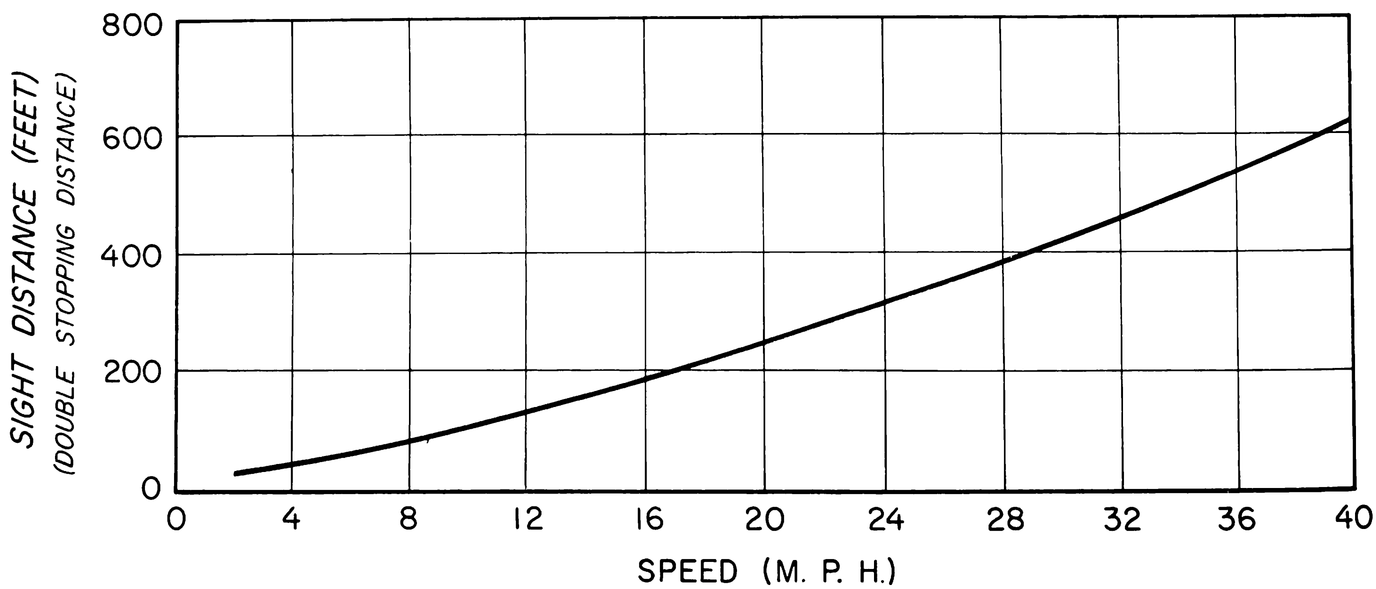

FIGURE 28.—Safe speeds as limited by sight distance, single-lane roads.

3. *Average Length of Curve on Logging Roads*

Observations were made of several logging roads to determine the radius of curvature in relation to central angle and its effect on travel time. The average for mountain-type roads is—

Radius (feet)	*Average central angle (degrees)*
100	85
200	55
300	40
400	30
500	24
600	20
700	17
800	15
1,000	12

4. *Calculation of Time for Negotiating Curves*

It would be a prodigious time-consuming job to calculate the effect on travel time of all possible combinations of grade and curvature. In this report, calculations were made on the basis of a gravel-surfaced road with a −2-percent grade in the direction of travel of the loaded truck. This grade would give the greatest travel speed; consequently, the effect of alinement would be most apparent.

Deceleration time was assumed to be one-third of acceleration time, since ordinarily braking horsepower is about three times engine horsepower. Therefore, the combined acceleration plus deceleration time was considered to be 1.33 times the acceleration time.

Figure 26 shows the acceleration distance for typical empty and loaded trucks in the 60,000- to 86,000-pound class, with $B=1.75$ for loaded and $B=5.0$ for empty. This figure was computed by using the method described on p. 51.

Table 20 is an example of the method of calculating combined effect of deceleration, speed on curves, and acceleration for various radii of curvature and number of curves per mile. The first step in the calculation is to determine the length of curve from the radius and central angle as described in No. 3 above.

The length within the curves can then be determined, and the remainder, in the distance of 1 mile, is the tangent distance. From figure 26, acceleration and deceleration distances are determined and their total subtracted from the total tangent distance to get the length of tangent unaffected by the curves. The velocity on the curve is found from figure 28, p. 54, for single lane roads. Average velocity while decelerating and accelerating is found as the mean of the velocity on the curve and the velocity corresponding to a −2-percent grade, from Section A of this appendix, p. 45. The times for the curve distances, the deceleration plus decelerating distance, and for the tangent distance, are then found by dividing those distances by the corresponding velocity. Total time and average velocity are then calculated.

Figures 10 through 13 (pp. 12–15) give the time required for one mile of travel for various alinements on different classes of road. Although the computations for these charts are based on the assumption that all curves are uniformly spaced and that the same radius of curvature is used throughout the mile, which condition would be unlikely, the results agree quite closely with computations based on field tests in which the *average* radius of curvature for a section was used.

For double-lane roads the average radius should include only those curves with radii less than 700 feet, since there is little or no effect of such curves on speed until the maximum of 40 m.p.h. is reached.

For single-lane roads, the results will be reasonably accurate if the curves included in the average are limited to those with a radius of less than four times the shortest radius in the mile considered. The reason for this is that a sharp curve slows the vehicle so much that other curves of considerably longer radius encountered during the deceleration and acceleration distance do not affect the speed.

Table 21, giving examples taken from the field test sections, shows the actual speed attained as compared to the theoretical speed obtained from figures 10 to 13, inclusive. Actual speeds attained are the average of several trips over the section considered. It will be noted that, even though the grade and other conditions are different than those on which the calculations are based, there is a remarkably close correlation between calculated and observed values.

C. *Effect of Spacing on Turnouts and Traffic Density on Speed on Single-Lane Roads*

It is the usual practice on single-lane logging roads for an empty truck to stop on turnouts and allow a loaded truck to pass without materially reducing its speed or causing it to stop. Turnouts are usually intervisible. Assuming this condition to exist, the time lost by an empty truck being passed by a loaded truck would be as follows:

(a) The time required for the loaded truck to approach and pass the empty truck.

(b) Reaction time for the driver of the empty truck to start his vehicle after the loaded truck passes.

(c) Time for empty truck to accelerate to normal speed less the time it would have taken for empty truck to go the same distance at normal speed.

The time required for the empty truck to decelerate and park on the turnout is assumed to be the same as the time required for the loaded truck to cover one-half the distance between turnouts. It is not necessary to consider deceleration time for the empty truck, because the time will norm-

TABLE 20.—*Speed of empty truck on curves of single-lane road (14′ wide, 3′ ditch; 1:1 back slope; 1 mile long)* [1]

Radius (feet)	Curves per mile	Central angle	Speed on curves	Length curves	Length tangents	Length *a* and *d*	Length unaffected	*Vc*	*Va* and *Vd* average	Maximum V on tangent	*Tc*	*Tat* and *Td*	*Tt*	Total time	Total time	Speed
	Number		*M.p.h.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft./sec.*	*Ft./sec.*	*Ft./sec.*	*Sec.*	*Sec.*	*Sec.*	*Sec.*	*Min.*	*M.p.h.*
50	2	120°	7.5	209	5,071	5,071	0	11.0	41.20	71.4	19.0	123.0	0	142.0	2.37	25.3
	4			419	4,861	4,861	0		35.25	59.5	38.0	137.9	0	175.9	2.93	20.5
	8			838	4,442	4,442	0		29.35	47.7	76.0	151.3	0	227.3	3.79	15.8
	16			1,676	3,604	3,604	0		23.45	35.9	152.0	153.6	0	305.6	5.09	11.8
	24			2,513	2,767	2,767	0		19.60	28.2	228.0	141.2	0	369.2	6.15	9.7
100	2	85°	10.2	297	4,983	4,983	0	15.0	43.05	71.1	19.8	115.7	0	135.5	2.26	26.5
	4			593	4,687	4,687	0		37.05	59.1	39.6	126.5	0	166.1	2.77	21.7
	8			1,187	4,093	4,093	0		30.80	46.6	79.3	132.8	0	212.1	3.54	16.9
	16			2,374	2,906	2,906	0		24.60	34.2	158.5	118.1	0	276.6	4.61	13.0
	24			3,560	1,720	1,720	0		20.50	26.0	238.0	83.9	0	321.9	5.36	11.2
200	2	55°	14.2	384	4,896	4,896	0	20.8	45.30	69.8	18.4	108.0	0	126.4	2.11	28.4
	4			768	4,512	4,512	0		39.80	58.8	36.8	113.8	0	150.6	2.51	23.9
	8			1,536	3,744	3,744	0		33.50	46.2	73.9	111.7	0	185.6	3.09	19.4
	16			3,072	2,208	2,208	0		27.05	33.3	148.0	81.6	0	229.6	3.83	15.7
	24			4,608	672	672	0		22.55	24.3	222.0	29.8	0	251.8	4.20	14.3
300	2	40°	16.8	419	4,861	4,861	0	24.7	47.90	71.1	16.9	101.4	0	118.3	1.97	30.4
	4			838	4,442	4,442	0		41.90	59.1	33.8	106.0	0	139.8	2.33	25.7
	8			1,676	3,604	3,604	0		35.65	46.6	67.6	101.0	0	168.6	2.81	21.3
	16			3,351	1,929	1,929	0		29.35	34.0	135.2	65.7	0	200.9	3.35	17.9
	24			5,027	253	253	0		25.25	25.8	203.0	10.0	0	213.0	3.55	16.9
400	2	30°	18.9	419	4,861	4,861	0	27.8	49.60	71.4	15.1	98.0	0	113.1	1.89	31.7
	4			838	4,442	4,442	0		43.60	59.4	30.2	101.8	0	132.0	2.20	27.3
	8			1,676	3,604	3,604	0		37.65	47.5	60.4	95.7	0	156.1	2.60	23.1
	16			3,351	1,929	1,929	0		31.70	35.6	120.8	60.8	0	181.6	3.03	19.8
	24			5,027	253	253	0		28.20	28.6	181.0	9.0	0	190.0	3.17	18.9
600	2	20°	22.0	419	4,861	4,861	0	32.4	52.05	71.7	12.9	93.3	0	106.2	1.77	33.9
	4			838	4,442	4,442	0		46.35	60.3	25.8	95.8	0	121.6	2.03	29.5
	8			1,676	3,604	3,604	0		40.70	49.0	51.6	88.5	0	140.1	2.33	25.7
	16			3,351	1,929	1,929	0		35.50	38.6	103.2	54.3	0	157.5	2.62	22.9
	24			5,027	253	253	0		32.70	33.0	155.0	7.7	0	162.7	2.71	22.1
800	2	15°	24.7	419	4,861	4,861	0	36.4	54.30	72.2	11.5	89.5	0	101.0	1.68	35.7
	4			838	4,442	4,442	0		48.85	61.3	23.0	90.9	0	113.9	1.90	31.6
	8			1,676	3,604	3,604	0		43.40	50.4	46.0	83.0	0	129.0	2.15	27.9
	16			3,351	1,929	1,929	0		38.95	41.5	92.0	49.5	0	141.5	2.36	25.4
	24			5,027	253	253	0		36.55	36.7	138.0	6.9	0	144.9	2.41	24.9
1,000	2	12°	27.0	419	4,861	4,861	0	39.6	56.10	72.6	10.6	86.6	0	97.2	1.62	37.0
	4			838	4,442	4,442	0		50.65	61.7	21.2	87.6	0	108.8	1.18	33.1
	8			1,676	3,604	3,604	0		45.60	51.6	42.4	79.0	0	121.4	2.02	29.7
	16			3,351	1,929	1,929	0		41.70	43.8	84.8	46.2	0	131.0	2.18	27.5
	24			5.027	253	253	0		39.80	40.0	127.0	6.3	0	133.3	2.22	27.0

[1] V=Velocity; a=acceleration; d=deceleration; T=time; t=tangent; c=curve.

TABLE 21.—*Comparison of theoretical speed controlled by curvature with actual speed from field tests*

Class of road	Truck loaded or empty	Grade	Length of test section	Curves	Equivalent curves per mile	Average radius	Theoretical time required	Actual time required
		Pct.	*Ft.*	*No.*	*No.*	*Ft.*	*Min./mi.*	*Min./mi.*
Single lane without ditch	Loaded	−5.5	7,500	14	10	254	3.75	3.77
Single lane with ditch	Empty	−.7	10,700	13	7	230	2.80	2.75
Do	do	−2.1	9,000	18	10	170	3.40	3.43
Lane and one-half with ditch	do	−3.27	8,800	10	6	160	2.70	2.68
Do	Loaded	−2.0	11,100	16	8	220	3.15	3.35
Do	do	−3.6	10,500	24	12	287	3.15	2.85
Double lane	do	−1.0	14,600	21	8	445	1.80	1.90
Do	Empty	+1.0	14,600	21	8	445	1.70	1.76

ally be less than the time for the loaded truck to travel one-half the distance between turnouts.

The distance required to accelerate the empty truck back to normal speed (for the empty) can be found in figure 26, p. 54, if it is assumed that the grade is a +2 percent against the empty truck. (This grade was selected as representing an average condition.)

The number of passings per mile of road would be equal to the number of loaded trucks per hour divided by the normal speed in miles per hour.

Let H=Number of loaded vehicles per hour
S_t=Turnout spacing
S_a=Distance required for empty truck to accelerate to normal speed
T_n=Normal time per mile
T_l=Lost time per mile for the empty truck, in minutes
v=Speed of loaded truck in miles per hour
V_l=Velocity of loaded truck in feet per second
V_e=Velocity of empty truck in feet per second

$$T_l=\frac{H}{60_v}\left(\frac{S_t}{2\ V_l}+3+\frac{2\ S_a-S_a}{V_e}\right)$$

For simplicity of calculation, it is assumed that $V_l=V_e$, in which case

$$T_l=\frac{H}{60_v}\left(\frac{S_t+2\ S_a}{2\ V_l}+3\right)$$

The effect of this lost time for a traffic density of 20 vehicles is shown in table 22. Since the time lost between turnouts is directly proportional to traffic density, it was possible to construct figure 16, p. 17, by using the average increase in travel time corresponding to the various turnout spacings.

D. *Delay Time*

Data were taken during field tests to determine the relative time involved in delays for large trucks as compared with delays for small ones. Table 23 shows delay time in minutes per M board feet or minutes per trip, whichever seems logical for the particular operation.

In loading and scaling, the time involved is greater for large trucks than for small ones, since it is directly in proportion to the number of M board feet per load. In unloading, however, time is not in proportion to load size, since only a part of it is involved in the actual unloading. About half the unloading time can be distributed on a per M-board-foot basis and the other half on a per trip basis. In all other delays, no more time is involved for large trucks than for small ones; these delays can be distributed on a per trip basis.

Using average data from table 23, table 24 shows the average delay time per M board feet for large trucks as compared with that for small trucks.

Figure 9, p. 11, shows the average delay time per M board feet for loads from 4 to 20 M board feet.

TABLE 22.—*Percent increase in travel time, by turnout spacing and a traffic density of 20 vehicles per hour*

Turnout spacing (feet)	Speed of loaded truck	Velocity of loaded truck	Distance for empty truck to accelerate to normal speed	Lost time per mile for empty truck	Normal travel time per mile	Increase in travel time
	M.p.h.	*Ft./Sec.*	*Ft.*	*Min./mi.*	*Min.*	*Percent*
1,000	30	44	710	0. 339	2. 00	16. 9
	25	36. 7	310	. 335	2. 40	14. 0
	20	29. 3	135	. 410	3. 00	13. 7
	15	22	52	. 621	4. 00	15. 5
	10	14. 7	13	1. 262	6. 00	21. 0
Average						16. 2
750	30	44	710	. 307	2. 00	15. 3
	25	36. 7	310	. 289	2. 40	12. 1
	20	29. 3	135	. 340	3. 00	11. 3
	15	22. 0	52	. 497	4. 00	12. 5
	10	14. 7	13	. 979	6. 00	16. 3
Average						13. 5
500	30	44	710	. 276	2. 00	13. 8
	25	36. 7	310	. 243	2. 40	10. 1
	20	29. 3	135	. 268	3. 00	8. 9
	15	22. 0	52	. 372	4. 00	9. 3
	10	14. 7	13	. 697	6. 00	11. 6
Average						10. 7
250	30	44	710	. 244	2. 00	12. 1
	25	36. 7	310	. 198	2. 40	8. 2
	20	29. 3	135	. 198	3. 00	6. 6
	15	22. 0	52	. 245	4. 00	6. 1
	10	14. 7	13	. 413	6. 00	6. 8
Average						7. 9

TABLE 23.—*Breakdown of delay time, by size of load*

Company	Size of load	Waiting for loader, per trip	Loading, per M bd. ft.	Scaling, per M bd. ft.	Waiting for unloader, per trip	One-half time unloading		Miscellaneous, per trip
						Per M bd. ft.	Per trip	
	M bd. ft.	*Minutes*	*Minutes*	*Minutes*	*Minutes*	*Minutes*	*Minutes*	*Minutes*
1	9. 90	27. 89	3. 17	0. 62	3. 87	0. 63	6. 24	7. 44
2	6. 49	40. 05	2. 99	. 61	19. 42	. 63	4. 12	17. 26
3	11. 16	27. 72	3. 59	. 00	1. 25	. 45	5. 04	8. 26
4	7. 37	9. 68	3. 94	. 00	13. 76	. 40	2. 94	18. 78
5	6. 65	18. 01	3. 94	. 00	3. 80	. 65	4. 33	9. 85
6	6. 11	5. 88	3. 33	. 00	. 00	. 97	5. 93	3. 34
7	5. 38	16. 42	3. 84	. 83	1. 17	. 84	4. 53	9. 56
8	9. 60	7. 90	3. 99	. 79	12. 20	. 73	7. 00	11. 70
9	4. 48	9. 01	5. 42	1. 40	1. 13	1. 67	7. 50	12. 83
10	6. 30	13. 40	3. 45	. 00	. 00	1. 13	7. 10	9. 80
Average		17. 60	3. 77	. 85	5. 66	. 81	5. 47	10. 88

TABLE 24.—*Average delay time per M board feet, by kind of delay*

Kind of delay	Delay time when board-foot load is—								
	4 M	6 M	8 M	10 M	12 M	14 M	16 M	18 M	20 M
	Minutes	*Minutes*	*Minutes*	*Minutes*	*Minutes*	*Minutes*	*Minutes*	*Minutes*	*Minutes*
Waiting for loader	4. 40	2. 83	2. 20	1. 76	1. 47	1. 26	1. 10	0. 98	0. 88
Loading	3. 77	3. 77	3. 77	3. 77	3. 77	3. 77	3. 77	3. 77	3. 77
Scaling	. 85	. 85	. 85	. 85	. 85	. 85	. 85	. 85	. 85
Waiting for unloader	1. 42	. 94	. 71	. 57	. 47	. 40	. 35	. 31	. 28
Unloading	2. 18	1. 72	1. 48	1. 36	1. 27	1. 20	1. 15	1. 11	1. 08
Miscellaneous	2. 72	1. 81	1. 36	1. 09	. 90	. 78	. 68	. 60	. 54
Total	15. 34	11. 92	10. 37	9. 40	8. 73	8. 26	7. 90	7. 62	7. 40

APPENDIX 2. HAULING COSTS

A. *Definition*

Hauling costs as determined in this report include all costs except road amortization and maintenance costs and taxes or fees paid in lieu of these costs.

B. *Elements of Cost*

1. *Classification of Costs*

The items that make up the total hauling cost may be classified as follows:

a. *Fixed costs*

Costs paid for on an annual basis regardless of the amount of driving that is done during the year. They include the following:

(1) Depreciation on truck and trailer without tires
(2) Interest on money invested in truck, trailer, and tires
(3) Fire and theft insurance
(4) Personal liability and damage insurance
(5) Collision insurance

b. *Dependent costs*

Costs that are chargeable against the hauling operation while it is actually going on, but not chargeable during the periods it is shut down. These costs are as follows:

(1) Driver's wage, including annual leave
(2) Social security tax
(3) Unemployment compensation
(4) Administration
(5) Industrial insurance

c. *Operating costs*

Costs incurred by the operation of the truck. These are

(1) Fuel
(2) Lubrication (including oil, grease, and servicing)
(3) Repairs to truck and trailer

d. *Tire costs*

These include the initial cost of the tires and the cost of repairs and labor to keep them serviceable during their useful life.

2. *Distribution of Costs*

In examining and comparing the costs of various logging companies, it was found that the best correlation between costs could be obtained for some on a time-of-operation basis and for others on a mileage basis. Fixed costs and dependent costs should definitely be considered on a time basis, since that is the basis on which they are established.

Fuel consumption is a function of engine speed and average percentage of maximum engine load capacity during the time of operation. Because a truck engine is usually operating at or near a constant r.p.m. and the speed on the road is varied varied largely by shifting to higher or lower gears, fuel consumption is more nearly constant on a round-trip-a-minute-of-operation basis than on a mileage basis.

Lubrication of the engine is a function of the r.p.m. of the engine. Since the r.p.m. is more or less constant, the amount of lubrication is more nearly constant on a minute-of-operation basis than a mile basis.

Engine repairs are likewise a function of the engine r.p.m. and should be considered on a minute-of-operation basis.

Lubrication and repair for the engine and chassis are probably dependent on frequency of vibrations in travel. This cost could be figured either on a minute or a mile basis. Because it is relatively small, it has little effect on total cost, regardless of which method is used. Since there was no segregation between engine and chassis lubrication in most of the company records upon which these costs were based, they are grouped together on a minute-of-operation basis.

Tire costs should definitely be considered on a mile basis; to consider them on a minute basis would give a lower tire cost for high speeds than for low speeds.

The distribution of total costs are considered in this analysis as follows:

a. *Time basis*
 (1) Fixed costs
 (2) Dependent costs
 (3) Operating costs
b. *Mileage basis*
 (1) Tire costs

3. *Determination of Costs*

a. *Fixed costs*

(1) *Depreciation* is computed on an 8-year basis, assuming a 6-percent salvage at the end of that time. The depreciation was considered to be on the cost of the truck and trailer only, because the cost of the tire is taken up under "Tire cost." The original cost of truck and trailer was obtained from seven leading truck manufacturers and four trailer manufacturers, and the cost for each weight class, as determined by the tire capacity, is the average cost of these different makes of trucks and trailers.

(2) *Interest* is computed at 6 percent for the investment in truck and trailer including tires.

(3) *Fire and theft insurance* is figured from data furnished by insurance companies and is based on 80 percent of the average value of the hauling unit throughout its usable life.

(4) *Personal liability and property damage insurance* is computed on a basis of average fleet rates in areas of low-density population with a coverage of $10,000/$20,000.

(5) *Collision insurance* is based on "$250 deductible" on the average value of the truck less trailer at fleet rates in areas of low-density population.

Property taxes and license fees are not included in fixed costs, because they are usually considered as a State revenue to cover road maintenance.

The above fixed costs are distributed on a basis of a 10-hour day, a 5-day week, and a 12-month year. Thus, during the time when a truck is delayed or when no hauling is being done, these costs go on as usual. Since there are, on this basis $60\times10\times5\times52=156{,}000$ working minutes per year, the cost per minute for each of the above items would be

$$\frac{1}{156{,}000}\times\text{annual cost for each item}$$

b. *Dependent costs*

(1) Driver's wage is assumed to be $2.32 per hour. Time-and-one-half is allowed for time in excess of 40 hours per week, and 2 weeks' vacation with pay is allowed per year. The driver's annual pay if he worked the full year would be as follows:

Regular time	$=40\times\$2.32\times50$	$=\$4,640.00$
Overtime	$=10\times\$2.32\times50\times1.5$	$=1,740.00$
Vacation	$=40\times\$2.32\times2$	$=185.60$
		6,565.60

During this time he works

$$60\times10\times5\times50=150{,}000 \text{ minutes;}$$

therefore, his rate of pay per minute is

$$\frac{\$6{,}565.60}{150{,}000}=\$0.0438$$

(2) *Social security* is computed at 1.64 percent of the payroll.

(3) *Unemployment compensation* is assumed to be equal to 2.7 percent of the payroll for the average logging company.

(4) *Administration*, including supervising, clerical, and other overhead, chargeable against hauling, is assumed to be equal to 20 percent of the payroll.

(5) *Industrial insurance* is assumed to be equal to 11 percent of the payroll for the average logging company.

c. *Operating costs*

(1) *Fuel cost.*—Field tests indicate that the fuel consumption per minute for round trip travel can be assumed to be reasonably constant for all grades. This seems reasonable, especially for steep grades where the truck runs at full throttle up grade and at or near a minimum on the return trip. This assumption is further justified by data published in Oregon State Highway Commission's Technical Bulletin No. 5 (1937). In the following tabulation, data for columns (1), (2), and (3) are taken from figure 52 of that bulletin:

Composite grade (pct.)	*Speed (m.p.h.)*	*Fuel consumption (mi./gal.)*	*Rate of fuel consumption (gals./min.)*
(1)	(2)	(3)	(4)
0	36. 0	5. 6	0. 107
1	34. 0	5. 5	. 103
2	30. 0	4. 9	. 102
3	24. 0	4. 0	. 100
4	19. 5	3. 3	. 099
5	16. 0	2. 7	. 099
6	13. 2	2. 3	. 096
Average			. 101

TABLE 25.—*Round trip fuel consumption for various sizes of gasoline and diesel trucks* [1]

Item	Truck sizes in pounds, g.v.w.—				
	50,000–60,000	60,000–80,000	80,000–96,000	96,000–114,000	114,000–207,000
Average size engine____hp__	100–125	125–150	150–200	200–265	265–300
Gasoline consumed per round trip minute travel time__gals__	0. 102	0. 121	0. 162	0. 215	0. 243
Diesel fuel consumed per round trip minute travel time gals__	----------	. 071	. 096	. 126	. 143

[1] Based on field tests.

Table 25 is based on round trip fuel consumption with the truck loaded one way and empty the other. It is therefore representative of the average percentage of full-load engine output for the round trip for existing road conditions. For highways with an alinement that does not limit speed, it seems reasonable to assume that the percentage of full-load engine output for the round trip would be increased and that the fuel consumption per minute would therefore be somewhat greater. For roads with poor alinement or roads where the speed is otherwise reduced below that which the engine is capable of, the fuel consumption per minute would be somewhat decreased. Such variations were observed in the field data, but they were relatively small. Therefore, it is believed that table 25 shows fuel consumption for all types of road conditions with reasonable accuracy. In this analysis, fuel costs per gallon were 16 cents for diesel oil and 22.2 cents for gasoline. This does not include the tax.

(2) *Lubrication costs.*—According to data compiled from logging companies' records, the average lubrication cost is equal to 13 percent of the fuel cost for gasoline trucks and 29 percent of the fuel cost for diesel trucks.

(3) *Repairs for truck and trailer.*—The data in table 26, compiled from logging company records for 1957, are for repair costs that included parts and labor. Assuming that the cost of keeping a truck and trailer in operating condition during the unit's useful life will be in proportion to the original cost of the unit, table 27, which is based on table 26, shows the average repair cost for gasoline and diesel units.

TABLE 26.—*Repair costs for diesel and gasoline units, 1957*

DIESEL UNITS

Company	Repair cost per minute driving time	Actual g.v.w.	Average cost new truck and trailer	Repair cost per minute per $1,000 initial cost
	Dollars	*Pounds*	*Dollars*	*Dollars*
2____	0. 0595	57, 000	18, 100	0. 00329
3____	. 1572	107, 760	25, 900	. 00607
8____	. 1590	140, 010	38, 100	. 00417
14____	. 1460	91, 080	20, 200	. 00723
15____	. 1320	103, 120	20, 200	. 00653
16____	. 0833	99, 124	27, 300	. 00305
17____	. 0756		--------	--------
18____	. 0481	70, 375	22, 500	. 00214
21____	. 2040	105, 400	25, 900	. 00788
22____	. 0742	60, 108	19, 500	. 00381
23____	. 0940	123, 240	30, 000	. 00313
Average____	--------	--------	--------	. 00473

GASOLINE UNITS

Company	Repair cost per minute driving time	Actual g.v.w.	Average cost new truck and trailer	Repair cost per minute per $1,000 initial cost
	Dollars	*Pounds*	*Dollars*	*Dollars*
4____	0. 0293	65, 210	13, 500	0. 00217
6____	. 1720	106, 810	25, 900	. 00664
7____	. 0859	115, 835	25, 000	. 00344
10____	. 0611	66, 515	13, 900	. 00440
19____	. 0693	56, 200	13, 500	. 00513
20____	. 1130	98, 000	25, 960	. 00436
Average____	--------	--------	--------	. 00402

TABLE 27.—*Average repair cost for various sizes of gasoline and diesel units*

G.v.w. (pounds)	Cost, new truck and trailer, less tires	Repair cost per minute of driving time	
		Gasoline unit	Diesel unit
	Dollars	*Dollars*	*Dollars*
50,000 to 60,000	12, 900	0. 0559	----
60,000 to 86,000	21, 609	. 0869	0. 1022
86,000 to 103,000	25, 300	. 1017	. 1197
103,000 to 122,000__	31, 000	. 1246	. 1466
122,000 to 164,000___	38, 100	. 1532	. 1802
164,000 to 207,000___	43, 400	. 1745	. 2053

d. *Tire costs*

Few records are available that give the cost of tires operated over any one type of surface. In order to determine the relative cost over paved, dirt, and gravel surfaces, the following record was taken from three companies using on-the-highway trucks:

Company	*Tire cost per mile*	*Paved road*	*Gravel road*	*Dirt road*
	(*dollars*)	(*percent*)	(*percent*)	(*percent*)
1	0.0316	95	3	2
2	.0583	57	43	0
3	.0926	48	0	52

Let x=cost on paved roads (oiled, asphalt, or concrete)
y=cost on gravel roads (crushed to 1-inch minimum)
w=cost on dirt roads (native clay and rock mixture),
then the following equation can be set up for each of the above companies:

$$.95x+.03y+.02w=0.0316$$
$$.57x+.43y+0 \quad =0.0583$$
$$.48x+.0 \quad +.52w=0.0926$$

Solving these equations, the following values are obtained:

$$x=0.031$$
$$y=0.094$$
$$w=0.150$$

	Pavement	*Gravel*	*Dirt*
Value	$0.031	$0.094	$0.150
Ratio	1.00	3.03	4.84

The following tabulation is based on the assumption that the wear on tires is in proportion to the number of times any spot on the tread of the tire comes into contact with the road surface per mile:

G. v. w. (*pounds*)	*Tire size commonly used*	*Tires* (*number*)	*Contacts per mile of road* (*number*)	*Ratio*
50,000–60,000	10 x 20	18	498	1.000
60,000–86,000	10 x 22	18	477	.9570
86,000–103,000	11 x 22	18	464	.9320
103,000–122,000	12 x 24	18	432	.8670
122,000–164,000	14 x 24	18	396	.7950
164,000–207,000	16 x 24	18	355	.7130

Based on the ratios in the preceding tabulation, table 28 shows tire cost per mile for various sizes of truck and trailer units and types of surface. In using this method of calculating tire cost, it is assumed that such cost is in direct proportion to the cost of a new set of tires and that the vehicle load is properly placed so that the tires carry no more than the load specified by the manufacturer.

The values in table 28 are compared with values in table 29, which were taken from the book records of 11 logging companies. Note the closeness of computed and actual tire cost per mile. The cost of tires operated over dirt roads that have no rock material in them larger than would be found in a gravel surface (1 inch minus) is the same or slightly less than that shown for the gravel surface.

4. *Tabulation of Elements of Cost*

Tables 4 and 5, pp. 20 and 21, show hauling costs for gasoline and diesel units according to the following classifications:

(a) Fixed costs per minute
(b) Dependent fixed costs per minute
(c) Operating cost, less tires, per minute
(d) Tire cost per mile

TABLE 28.—*Tire costs per mile for various sizes of truck and trailer units and types of surface*

Number and size of tires	Maximum allowable load	Cost of set of tires	Tire cost per mile of— Paving	Gravel	Dirt
	Pounds	*Dollars*	*Dollars*	*Dollars*	*Dollars*
18—9 x 20	72,900	2,005.00	0.0256	0.0776	0.1239
18—10 x 20	86,040	2,519.00	.0310	.0940	.1500
18—11 x 20	90,900	2,925.00	.0351	.1062	.1645
18—10 x 22	91,800	2,660.00	.0314	.0951	.1518
18—11 x 22	106,380	3,130.00	.0358	.1086	.1733
18—11 x 24	112,860	3,824.00	.0420	.1274	.2033
18—12 x 24	133,740	4,673.00	.0498	.1512	.2412
18—14 x 24	169,200	8,337.00	.0813	.2467	.3940
2—12 x 24 2—16 x 24	221,400	11,097.00	.0974	.2953	.4712

TABLE 29.—*Comparison of derived tire costs with actual 1957 costs*

Company	Number and size of tires	G.v.w.	Tire cost per mile of—			Computed cost per mile	Actual cost per mile
			Pavement	Gravel	Dirt		
		Pounds	*Percent*	*Percent*	*Percent*	*Dollars*	*Dollars*
1	18—10 x 20	57, 000	57	43	0	0. 0581	0. 0583
2	18— 9 x 20	65, 200	95	3	2	. 0316	. 0316
3	18—10 x 20	59, 800	64	28	8	. 0582	. 0664
4	18—11 x 24	106, 800	0	100	0	. 1274	. 1220
5	18—11 x 22	98, 500	0	91	9	. 1144	. 1000
6	18—10 x 22	71, 800	70	30	0	. 0505	. 0529
7	18—10 x 22	70, 400	77	20	3	. 0475	. 0419
8	18—10 x 20	56, 200	48	0	52	. 0920	. 0926
9	18—12 x 24	98, 000	45	44	11	. 1155	. 1260
10	18—10 x 20	60, 200	75	0	25	. 0607	. 0735
11	18—11 x 24	107, 500	65	35	0	. 0719	. 0810

C. *Hauling Cost by Period*

To enable ready calculation of hauling cost when length of haul, time of haul, delay time, and length of shutdown period are known, tables 7 and 8, pp. 24 and 25, were prepared to show the cost by periods for gasoline and diesel units, respectively. In these tables the following symbols are used:

- J=Costs that occur during shutdown periods; these are made up of fixed costs only.
- N=Costs that occur when the truck is in service but not hauling logs. This cost occurs when the truck is being loaded and unloaded, or is waiting to be loaded or unloaded, or when it is held up for similar delays. This item includes fixed costs and dependent costs.
- C=Costs that occur only when the vehicle is traveling, less tire costs. This item includes fixed costs, dependent costs, and vehicle operation costs.
- D=Tire cost.

Costs J, N, and C are shown in minutes, and costs D are shown in miles.

D. *Hauling Cost—Total*

Based on the breakdown of costs by periods, figures 18 to 21, inclusive, (pp. 26 to 29) can be used to simplify the determination of hauling cost. It will be noted that total cost is determined by adding together the separate costs C_1, C_2, C_3, and C_4.

These values were determined as follows:

$$C_1=2D+Ct$$

$$C_2=\frac{NOZ}{L}$$

$$C_3=J\left(\frac{12}{Y}-1\right)t$$

$$C_4=J\left(\frac{12}{Y}-1\right)\frac{QZ}{L}$$

where

J, N, C, and D are as defined in Section C above and are as shown in tables 7 and 8

and

- t=Time per round trip mile
- L=Total length of haul
- Y=Months of working season per year
- Q=Total M board feet per load
- Z=Delay time per M board feet in minutes (fig. 9, p. 11)

Because hauling cost for gasoline and diesel units is approximately the same, figures 18 to 21, inclusive, are for gasoline trucks only.

APPENDIX 3. COST OF ROAD MAINTENANCE

This report does not include a determination of road maintenance costs. For the handbook user's convenience, the following tabulation shows maintenance costs in Oregon for roads with heavy log haul during calendar years 1955–57:

	East of Cascade Range		*West of Cascade Range*	
	Miles (number)	*Average cost per mile (dollars)*	*Miles (number)*	*Average cost per mile (dollars)*
Surface:				
Bituminous macadam	14	608	15	1, 439
Oil macadam	250	701	21	775
Asphaltic pavement	21	302	22	587
Untreated macadam	45	1, 439	14	777
Concrete pavement	[1] 408	------	------	-------

[1] 408 miles at $394 per mile for maintenance—statewide data not available for this type of road with heavy log hauling.

APPENDIX 4. STATE AND FEDERAL TAXES AND FEES PAID FOR ROAD USE AND MAINTENANCE

Although costs as determined in this report do not include highway-use taxes, this appendix has been prepared to indicate the approximate amount of these taxes.

Federal tax for highway use

Federal tax for fuel is 3 cents per gallon. Based on average gasoline-use figures, as determined elsewhere in this report, the tax per round trip mile is as follows:

G.v.w. (pounds)	*Federal tax per round trip mile (dollars)*
60,000	0.0120
72,000	.0144

State tax for highway use

State taxes vary for highway use in both amount and method of assessment. In general, these taxes are made up of both lump-sum assessments and sales tax on fuel consumed. For the purpose of this appendix, only the State of Oregon is considered.

Oregon has made an extensive study of highway costs occasioned by heavy trucking, and since January 1, 1952, the tax has been based on the size of unit as well as the total number of miles hauled. Limiting loads are approximately 60,000 pounds for single axle-driven trucks and 72,000 for dual axle-driven trucks. The State tax is 6 cents per gallon. Average gasoline consumption and State tax for these trucks are as follows:

G.v.w. (pounds)	*Gasoline consumed per round trip mile (gallons)*	*State tax per round trip mile (dollars)*
60,000	0.402	0.0241
72,000	.484	.0290

Public Utility Commission fees in Oregon are based on gross vehicle weight. The tax for gasoline trucks is as follows:

Rated g.v.w. (pounds)	*P.U.C. fee per round trip mile (dollars)*	
60,000 loaded	0.0340	Truck and trailer.
22,000 empty	.0095	Truck only.
Total	.0435	
72,000 loaded	.0430	Truck and trailer.
23,000 empty	.0150	Truck only.
Total	.0580	

Total Federal plus State highway use tax per round trip mile in Oregon

	60,000-pound unit	*72,000-pound unit*
Federal fuel tax	\$0.0120	\$0.0144
State fuel tax	.0241	.0290
State P.U.C. fees	.0435	.0580
Total	.0796	.1014

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